Oral History of Gordon Robilliard and Paul Dayton. 5 March 2012

PETER: Today is March Fifth, 2012 at Scripps Institution of Oceanography Archives. I'm Peter Brueggeman, and we are interviewing two charismatic individuals. They will introduce themselves and their affiliations and then I'll make some more remarks. Could you introduce yourselves, please?

PAUL: I'm Paul Dayton. I'm Professor Emeritus at Scripps.

GORDON: I'm Gordon Robilliard and I'm a Senior Consultant and Director Emeritus with Cardno ENTRIX, a private environmental consulting firm. I live in Gig Harbor, Washington.

PETER: As we have this conversation, when you refer to people, please refer to them by first name and last name. For the record, we need to know to whom you're referring. The famous example is “Curly” who is Donald Wohlschlag.

We're here to talk about how marine biology research got going at McMurdo Station in Antarctica in the mid-1960s. You two were definitely key players if you look back. You had really the first extensive diving research program there. The people before you were either, as we've learned from other interviews, in the water without the knowledge of the authorities, and/or just did a few dives. They didn't really have the free rein that you two did to do things. It didn't just happen from nothing that you went there and started diving to do

research. It would be interesting if you would talk about how you got into scuba diving, because this was a really early period in scuba diving which pretty much started in the 1950s. Equipment wasn't very good for regular diving in temperate or tropical waters let alone diving to depths >100 feet under 8' of ice in 28^{o}F water 2000 miles from any recompression facilities. I certainly remember, for example, that not everybody had pressure gauges to know how much air they had in their tank; I didn't when I started out.

Could you first talk about how you got into scuba diving and then we'll talk about how that led into doing research at McMurdo.

PAUL: Maybe I'll just start and go through my scuba diving and then Gordon can talk about his. Then I'll go back to my diving experience in Antarctica. I started diving before Gordon did because I lived near the Gulf of California, and had just fallen in love with the underwater scene. However, I was not yet into the biology; I was mainly trying to kill fish.

I was having a hard time staying underwater by just snorkeling. At that point - this was 1954- we knew about Jacques Cousteau's scuba diving apparatus, but I'd never seen one. I just had seen pictures of it in an article in some magazine - *Scientific Mechanics* maybe.

GORDON: *Popular Science* maybe?

PAUL: Maybe. The article was how to build a B-29 regulator, which Cousteau modified to use underwater on an air tank. I was just a young teenager without even a driver's license, but I acquired

all the equipment, and made myself a tank that should have killed me. I acquired 3 discarded Fire Department air tanks from Pappadeas' Junk Yard on Stone Ave and used simple hardware pipes we threaded to hold the tanks together instead of any pressure system. We filled it off the big tank. I made quite a few dives with that setup before the regulator broke off and exploded behind my head.

This was in the '50s so then I went back to snorkeling and free diving. Then in the early '60s, you could buy single hose regulators. But my homemade rig was a double hose. In 1954 I think is pretty much when Jim Stewart, retired University of California Scripps Diving Officer, and the people at Scripps started their real science programs based on scuba diving operations. By the early '60s, I knew about them and I actually came out to the Scripps library to read their dive logs and fantasize about being a marine biologist.

We still didn't have wet suits. We had dry suits that we contrived variously but they always leaked and weren't very warm.

PETER: Like Bel Aqua dive suits?

PAUL: I had something with a thing in the middle that you tied up.

PETER: Front entry?

PAUL: Right. But the latex was bad quality in those days and it was always leaking. Wet suits were still not available to people like me anyway.

In summary, I started getting into more diving back in the very early '60s. I made quite a few dives in the Gulf of California as

a kid. Then in the '60s, I made quite a few more dives before the Antarctic program happened.

PETER: Your original motivation to dive was hunting for fish?

PAUL: That's an important point because I was just killing things, honestly, until Cousteau's movie came out. And then the book came out. It was *"Silent World"* that persuaded me that underwater nature was wonderful in its own right, but Cousteau was killing things in the movie and in the *"Silent World 2"* in those days, and so was I. I still feel really guilty for the things I killed even though we ate them all.

There was so much natural history that I learned in those books and movies that it just overwhelmed me. I kept killing and eating the fish but I spent almost all my time looking at the other critters after that. Cousteau's book had a huge influence on me when it came out in the early '50s.

GORDON: My diving career wasn't quite as dramatic a start. I grew up near Victoria, British Columbia, and spent a good share of my life till my early 20s (mid 1960s) near or on the marine environment. Like Paul, my goal was to: catch fish, crabs or shrimp; dig clams; collect oysters and other shell fish; and generally recreate on the water. I was generally aware of scuba diving but could not afford the equipment or lessons, and I was not nearly as adventuresome (or crazy?) as Paul to try to build my own scuba apparatus. However, when I started my graduate work at the University of Washington Friday Harbor Marine

Labs (FHL), I realized very quickly that if I was going to do anything like Paul was describing - that is be able to get underwater to study the submerged critters - I was going to have to learn to scuba dive. One of the marine technicians at FHL, Bob Myers, offered to teach me to dive. We started with snorkeling but quickly advanced to scuba. We borrowed some equipment and Bob gave me some basic lessons on use of the equipment and what to do if anything went wrong. I recall the primary safety rule was "Ascend as fast as your bubbles and keep on blowing out – do NOT hold your breath!!"

First dive I ever made was offshore in about 60 feet of water. Bob is a fishery biologist, he's a big strong guy, and he's got flippers that seemed five feet long to power his swimming underwater. We jumped in the water, and he took me down to the bottom.

PETER: What year was this about?

GORDON: 1965.

PETER: And in Washington State where the waters are devilishly cold.

GORDON: Yes, it was definitely cold. Bob, as a fisheries biologist, was a hunter, and he was swimming around with the fish to study them. I'm a benthic biologist and I was looking for nudibranch mollusks (also known as sea slugs). I was sitting more or less in one place looking for some critters. When I looked around, Bob was gone. So I learned to dive by myself from Day 1.

And as much as solo diving is now frowned upon, for the next six years, I did most of my diving at FHL and other non-Antarctic

locations by myself. I was at Friday Harbor most of that time as a graduate student. I probably made nearly two thousand dives in that time. I often made two or three dives a day, especially in the summertime when it wasn't quite so cold. It was all regular scuba equipment, with few specific modifications for the colder waters of the Washington/B.C, area. We did not even have Farmer John suits then. I spent quite a bit of time underwater.

PETER: At FHL, you just went diving straight off from the FHL shore?

GORDON: I dove all around the San Juan Islands plus British Columbia, Puget Sound, California, Hawaii, and anywhere else I could get a trip.

PETER: Also, beach or shore diving?

GORDON: I did some of that but most of it was from the boat. Sometimes I had a partner with me.

PETER: And FHL had its own compressor

GORDON: Yes, we had our compressor so we did not depend on a third party supplier for air. A good thing because, in those days, there were no commercial dive shops at Friday harbor. I was there by myself through most of fall, winter and spring quarters, except for the director of the lab and maybe a couple of other people.

PETER: You filled your own tank?

NEW SPEAKER: I had to look after myself. I maintained my own gear and fixed my own regulators when I had to. It was pretty much a *do-it-yourself* operation.

PETER: That is so different from institutional scientific diving these days.

GORDON: It definitely was different. In fact, in my last year at Friday Harbor, the director of the lab saw me coming in one day by myself. He made note of that by coming down and asking me if I'd been diving. I said, “Yes”, and he said, “Don't let me see you going out or coming back again by yourself.” He didn't say I couldn't do it; he just said don't let me see you doing it. And so he never acknowledged that saw me doing it again. It is definitely different now.

PAUL: That would have been late in the '60s, because we all dove by ourselves in the early-mid 1960s.

GORDON: In the last couple of years I was at FHL (1970-71), there was a move toward a much more structured, regulated and probably overall safer program with a Diving Officer, training requirements, etc. There was a group of us - Paul, myself, Charles Birkeland, Karl Mauzey, and three or four other people - who essentially were diving ”fools” and who were all a combination of “old fashioned” underwater naturalists and budding research ecologists. We were amongst the first cohort of people around the country that started spending extensive time underwater learning the ecology and natural history of the subtidal critters and their habitats

PETER: Maybe your recreational diver buddy would not want to dive with you as a naturalist underwater because it’s the same thing as diving with a photographer. If you're not doing the same thing, it's boring, because they are stuck in position and looking at something.

So you end up solo diving.

GORDON: Actually, I did a lot of underwater photography now that you bring it up. There was a real plus about not having somebody else with me or nearby because they didn't stir up the bottom. I had lots of problems with partners who would mess thing up for my photos.

PETER: So you had a lot of cold water diving experience by the time you hooked up with Paul for the Antarctic.

GORDON: That's the only place I'd done any diving. Even Monterey Bay, California was not especially warm.

PETER: That set you up perfectly for diving at McMurdo. It's not like you came from Florida.

GORDON: No. Definitely it was not.

PAUL: I had been diving with Gordon at FHL and in Puget Sound, so I knew about his diving experience in cold water when we got together for the Antarctic program. But maybe we should just go back to the early '60s, and get myself to McMurdo and back, because that's an important part of the story. I desperately wanted to become a marine biologist when I grew up. Earlier in my career, I had spent several summers doing archaeology including in the Arctic.

I put that Arctic experience in my graduate school applications and Donald Wohlschlag (‘Curly’) at Stanford saw that. He contacted me and asked if I would like to go to the Antarctic. That was almost a mythical place in 1962 and 1963, especially for me.

I agreed to do it and went down there. By my first

summer in the Antarctic, I had been diving a lot, probably much more than Jerry Kooyman, but he was down there with some fairly crude wet suit gear and made some dives, with me helping him.

I stayed down there for over a year from October 1963 until the end of 1964. I realized, looking down through the holes, that I could see the bottom almost anywhere in the nearshore. I realized that we could dive in this area even under the ice. Jerry had done some diving. Verne Peckham had made something like 37 reconnaissance dives before that and had taken a bunch of underwater pictures.

So I had a sense that a diving research program was something that could be done. It wasn't going to be my thesis at any time. When I went got back from McMurdo and went to the University of Washington, I started working in the intertidal which is a place where I could do solid ecological work with some assuredness of a successful dissertation in a reasonable time frame. It was easier to get access to my study areas and to manipulate environmental factors in my experiments. So my thesis was intertidal.

But, in the meantime I came off the *Ice* (the Old Antarctic Explorer's [OAE] fond and familiar description of the Antarctic) in January in 1965, and went straight to University of Washington (UW). I started negotiating with my major professor (Dr. Robert T. Paine) that he had to front an NSF-sponsored research grant in which I would go to the Antarctic and do a diving program. Bob was very supportive. He didn't know anything about the Antarctic and very little about diving (he is an intertidal ecologist), but he supported what we

were trying to do. I wrote the proposal with a lot of support and interaction with George Llano. I think the whole initial generation of marine biologists in the Antarctic owe their careers almost exclusively to George who was very supportive of students that were pushing the boundaries. George actually held my hand while I was writing the proposal.

It went in, probably late1965, maybe early 1966.

Now we can jump forward in time. I'll probably come back and talk a little bit about the year I spent wintering over (1963-64). Even though I was not diving, it set the stage for a lot of what we were able to do, which is important.

PETER: Why would Bob Paine be supportive of you going to McMurdo if you were focusing on intertidal stuff?

PAUL: I persuaded him that the intertidal shut down (and it really sort of does) during the northern Fall and Winter, which is the southern hemisphere Spring and Summer.

PETER: It wouldn't impede your progress with your dissertation research that you went to Antarctica?

PAUL: Well, it could have, but being sort of compulsive, I talked him into it. I don't think it really did affect my intertidal research. I think without Antarctica, my experience would have been the same. Gordon, this was also true for you, right?

GORDON: The initiation of this project for me, was that I was literally sitting at my desk one day and Paul walked in to ask “Gordon, do you want to go to the Antarctic to go diving?” My

immediate response was “Sure, why not?” Paul may be compulsive, but I was (and still am) really compulsive. He said, “Okay” and turned around and walked out. (As an aside but background for such an impulsive decision, I grew up never being more than 150 miles from Victoria B.C. When I started graduate school, I vowed to myself that I would go anywhere in the world anyone wanted to send me to do marine research so long as it was supported financially. This Antarctic program was one of those opportunities and one I have never regretted.)

We discussed the program over the next few months. : What was the core research focus and what were the hypotheses to be tested? How would we test them? How we were going to get equipment together? What we were going to do with that kind of equipment? What are the logistics and equipment requirements for diving in deep water under 8’+ of ice in water that is 28^{o}F? But, for me, it was a matter of “go for it”. Plus it seemed that this was all an academic discussion anyway because a graduate student proposal to dive in the Antarctic seemed unlikely to get funded in our lifetime.

A few months later, Paul walked in to my office and says, ”Get ready, our proposal is funded and we're going to the Antarctic.”

Then I asked myself “What did I get myself into?” I was in the same position as Paul with regard to my research. Whatever we did in the Antarctic was not integral to my dissertation project.

But my dissertation work on the ecology of subtidal nudibranchs was even less dominated by season et cetera than Paul’s

intertidal work. My major professor, Dr. Alan J. Kohn, was pretty flexible as he allowed that “It's your dissertation not mine, and it's all underwater so it really isn't seasonal to a large extent.”

When Paul came up with this opportunity to go to the Antarctic, I was really excited about the fact that I was going to do some traveling to places I never had any idea that I'd ever get to.

PETER: Paul, why did you want a second person along? You had some work conceived that you knew you needed to do?

PAUL: When I had wintered over, I worked with fish and did physiology respiration rates with fish. I was out on the ice all the time, catching them with traps. Frequently, I saw the seals coming up with fish in their mouth and I knew there was an interesting food chain there. The common impression is that the Antarctic is very cold and harsh and horrible. The scientific thing that interested me came from Jack Littlepage’s thesis, specifically that in the Antarctic, underwater is physically very stable and extremely predictable. It has a seasonal plankton bloom but it's very predictable. So my entire concept was that this was maybe the best place in the world to look at a marine biological community in diving depth, not much influenced by physical disturbances, episodic events, climatic changes and other things. And it was a place whereby biological interactions would structure the communities completely.

PETER: So physical factors were part of your thinking about the Antarctic benthic community.

PAUL: Yes, I think my premise was good science. The

key was that I didn't know what was going on in the marine environment, except that I caught fish, and could look down to see pretty things on the bottom.

The whole program was predicated on seals eating fish, and fish eating the polychaete worms. I knew the fish ate worms from the gut contents because I was really quite familiar with the fish. I had a short food web in my mind where seals ate fish that ate worms.

My overall approach to test predator impacts, which somewhat mirrored my intertidal research and the vogue of the day for marine intertidal ecologists, was to put various size, type and configuration of cages on the bottom to include and/or exclude prey and predators. The grant bought us something like 60 heavy duty steel mesh cages coated with epoxy to minimize corrosion. We had them made in Seattle and shipped in huge crates to McMurdo.

We assembled the cages on the Ice over a period of several weeks between dives. We had to protect the fish from the seals, so we constructed several huge cages from galvanized pipe. They were about 6-7’ feet long, 4’ wide, and about 4’ high as I recall. We tried to cover them with blankets so the fish would know it's a refuge. We also planned to look at the natural history of the polychaetes that the fish ate to see how they fit into the food web. It turned out that, after a few dives, we realized that the originally proposed program would not work. But, that is the nature and the background to the science.

PETER: You just answered my question, that's a lot of logistics right there, where you would need at least two people.

PAUL: There was never a doubt I was not going to do it by myself,

GORDON: Also, the Navy wouldn't let us do the diving as one person. They required at least a buddy diving system and they would have preferred, though did not require, that we had a surface tender.

PETER: The people who were solo diving were not doing it as part of an approved program?

PAUL: Some of the early divers for Zaneveld in 1963 were solo shore diving with a line, but beyond that I don't think I ever personally saw people solo diving in the Antarctic. That was just around Friday Harbor. That was never part of our plan.

PETER: You had to get somebody to dive with you.

PAUL: I had to get somebody. And because I wintered over, I knew how sensitive personalities were. Gordon had (and still does have) a pretty robust personality and I'd been with him a lot. I knew he was a strong guy who could deal with any stress and issues we had on the Ice. He was physically strong too; he often picked up both twin 72 scuba tank rigs, one in each hand, lifted and twisted them in the air and set them down in the back of the Power Wagon very gently!

So that's how we came together.

Another key issue was that the diving equipment was really primitive, especially compared to modern equipment, and we really had troubles over time with the regulators and things.

PETER: You had to provide your own equipment

whereas now it's supplied?

PAUL: Well, they had regulators for us but we had to get our wet suits. Just for perspective, at that time, wet suits were still not that popular or well-designed especially for real cold water. People were using them but there wasn't a science of them, to put it mildly. For example, one of our friends at Friday Harbor, Robert Vadas, got one from Harvey's in Seattle, the same place where we got ours for the second year (1968). Poor old Bob went diving alone off the pier at the FHL where he was in whole view of the classroom. Harvey's had glued his wet suit together with water soluble cement, so the seams dissolved, and we saw these pieces of neoprene floating up,

PETER: And they were not stitched?

PAUL: No, just glued. The neoprene floated up and pretty soon this naked pink butt came up out of the water. There is this guy swimming back pulling together neoprene ends plus the rest of his gear. As usual for a wet suit, he didn't have on a swimming suit. That was a lesson; always wear your swimming suit under your wet suit. Gordon, do you want to describe the first wet suits for the Antarctic.

GORDON: The first year, we designed the suits based on our knowledge of diving in the relatively cold winter-time waters of Puget Sound where water temperatures were in the high 40^{o}F range. The material was ¼ inch nylon-lined neoprene so each piece would slide one over the other.

We had a vest that had full arms, full hood and beaver tail but no zipper. This we pulled on first over our head. Then we put

on Farmer John pants with the feet attached, no arms and no zipper. Finally we had an outer jacket with full arms, hood, beaver tail and a reverse zipper to about mid-chest level. We would pull this over the inner jacket and pants and zip it up. We had to have the reverse zipper, because we couldn't get the second jacket on without one, even with the nylon lining. And talc powder, a wet suit diver's panacea in those days, did not help with the outer jacket if there was no zipper. Believe me, we tried to get the outer jacket on without a zipper!

PETER: So you had three layers over your torso.

GORDON: Right.

PETER: And that was a pretty good water seal, theoretically.

GORDON: In theory. However, with the hard use we gave them, the suits would soon leak in three places: arm pits, back of your neck and the crotch. Besides being pretty sensitive places, they are also areas where body heat loss is the highest so we knew leakage there could result in hypothermia. All wet suits, even now, leak in these places even with modern advances in sewing seams and fancy glues, and re-engineered styling.

PAUL: Tell them about Harvey's and "bellying up to the bar".

GORDON: The next year (1968), we went to Harvey's where they were known to have better quality suits with exceptions such as Paul's story about Bob Vadas. Paul and I told the store manager (a young man with more macho than salesmanship) that we wanted him to

make custom-made wet suits we had designed as we were going to be diving in deep, cold water.

His immediate response was to tell us that “I can tell you how to make a suit like that because I dive in deep, cold water here in Puget Sound in the winter”. Now, normally Paul and I'd let this pass. But, I said “We're diving to 180 feet of water where the water temperature is 28^{o}F. When was the last time you did that?” End of bragging and beginning of the process to get an improved wet suit system. We got our suits which served us well, though they still leaked in the back of the neck, armpits and crotch by the end of the season (about 150+dives).

PAUL: I think wet suits in the Antarctic were fine, but for the deep diving which we'll get to in a minute, they compressed down to almost nothing.

When you're walking around outdoors after a dive and it is literally -30 to -50^{o}F, you could hear the gas bubbles in the neoprene popping and the rubber cracking as it got brittle in the cold.

After a month or so, because we were making two dives a day, those suits didn't have much to them.

PETER: You wore them out that fast?

GORDON: Yes, by the end of the season (150-200 dives), we threw them away with respect to using them in the Antarctic . They were still marginally useful for diving in Puget Sound, so we kept them as backup suits for our Washington diving research programs.

A major challenge was that we couldn't find a way to develop a glove that went on the end of the vest or outer jacket sleeve to

minimize leakage around the wrist. Maybe just as well, as our handling of shells, sponges, cages, other materials, and that sort of thing caused the fingers to wear out. We got to the point towards the end of the dives and especially towards the end of the season, where we were really functioning with clubs, not fingers, at the ends of our arms.

PETER: How long were you underwater.

GORDON: Most of the time we would be pushing the US Navy Repetitive Dive tables; which I had to teach Doctor Dayton about.

PAUL: We both have fond memories of the National Science Foundation (NSF) deciding that, if we were going to have this intensive program which they were supporting, then we had to satisfy the Navy that we were safe divers. So NSF agreed with the Navy that we would go to Key West Florida and go through the initial two weeks of an eight-week USN UDT (*aka* SEALS) training course at the Navy diving school. Getting the Navy to bless us turned out to be sort of interesting.

GORDON: We turned up at Miami in August which, for me, was really an experience. I looked around to find out where the sauna OFF switch was, it was so hot and humid. As background, we were at the beginning two weeks of what was a longer course for the Navy UDTs. So this was a serious diving course with the first two weeks focused on scuba gear. The UDTs then go on from there.

Upon check-in at the Navy Diving School, we were ”invited” to turn up at 0500 the next morning for physical training (PT along with everybody else. We could run the two miles on the soft sandy

beach in our boots. Paul and I both allowed that we were civilians and we didn't think we wanted to do that or we needed to do that. We would be there at class at 0800. Well, already, we are bucking the system and not bending to authority and the Navy instructors, especially the Chief Petty Officer and Senior Navy Master Diver affectionately known to all as “Mother” didn't like that. Another thing they made us do is get in a pool and swim a hundred laps of the pool.

GORDON: I don't swim well. I can dog paddle but I never really learned to swim. That's why a diver has flippers and a wet suit for propulsion and flotation, and a snorkel for breathing.

When *Mother* wasn't looking, Paul and I switched out.

PAUL: I could swim so I did my laps fast. Then Gordon went out of the water and sat there pretending to be me. I went back in to swim Gordon 's laps. Thus he finished in time and passed the swim test.

GORDON: There are numerous other stories about our short stay at the Diving School, but there are at least two others that were pretty funny. First, they put us in a water tank, 80-foot tall, 10 feet in diameter and with a little window near the bottom. On a slate, “Mother” who was outside the tank, would write instructions such as “Switch regulators and buddy breath” and that sort of stuff. What he didn't tell us is that he put one of his divers in at the top who then came down behind Paul to grab Paul's regulator out of his mouth. Paul immediately turned around and grabbed his regulator in a basic but unplanned “buddy breathing situation”.

PAUL: It seemed he was a buddy breather as far as I was concerned; no cause for panic! We got checked off on that one.

PETER: That was the old style of scuba instruction, creating stress situations.

PAUL: We weren't stressed; we were pissed off. Tell them about the class.

GORDON: Neither of us come from military families so we didn't understand that the instructor standing up there in front of a class is “God”. He might be only an enlisted man and he might have admirals in the class, but even they don't argue with the instructor. We didn't know that. This instructor was going on about Boyles’ Law, Henry's Law, Charles’s Law, and a bunch of other things related to pressure effects, and he had them all mixed up.

PAUL: Couldn't prove it by me, I never heard of any of them. I am not fond of laws.

GORDON: Like any good graduate student in science, I was questioning and correcting him. That didn't go over very well. Finally he just stopped the class and said ‘I'm going to go up and talk to the medical officer and get this straightened out. We will come back in ten minutes.” We came back in ten minutes and he screwed them all up all over again.

PAUL: But differently.

GORDON: Yes, so by now we had decided to adopt a ”Never mind, let’s just get through this and get out of here.” But I'll have to say, as an aside, if I had to pick a diving partner to keep me out of

trouble, I'd go with a SEAL any day. They may not have known their theory but they sure are world-class divers.

PAUL: They got tired of us, so tell them about the final exam.

First though, let me just interrupt to give you an overview of the whole time frame of our planned two-week class. The first or second day, Gordon tried to educate the instructor on all these laws I never heard of. By the second day, we had done the thing where I ripped the mouthpiece out of the guy's mouth. Immediately after breakfast on the morning of the fourth day, we came in to talk to the commanding officer of the whole place and he decided we were experienced divers. So why don't we just run through the "final" exam.

GORDON: The final exam on Day 3 was probably not intended to be "final" but rather as a way of putting us upstarts in our place so we would be more humble and quit harassing the instructors. "Mother" and his crew put us on an LST and took us about a mile offshore in about 15 feet of water.

Mother instructed the three of us to jump in the water in scuba gear with a compass and a line between us. I had the compass. He pointed out that on shore about a mile away, there was a tall orange and white striped navigation pylon with two smaller pylons, one on either side. There was a hundred yards between the smaller pylons. We were to take a compass bearing on the pylon(s) and swim toward shore. We could come up three times in that distance to re-orient ourselves. When we got to shore, we had to be somewhere between those two outer pylons.

We also had a time limit though I do not recall what it was but it was generous.

PETER: Underwater navigation for a mile?

PAUL: I couldn't see the pylons. I never saw the beach. It was way far away.

GORDON: I could kind of see them but not very well. I had the compass and was in the middle. “Mother” didn't tell us a relatively strong current was running parallel to the beach; in fact he gave us no useful information at all so it was up to us. Once we were in the water we could see that the seagrass was laid over in the current so we could adjust easily for that. I had used a compass a lot in my research in the San Juan Islands and both Paul and I were used to diving with currents, so that was not a big deal. Paul and I started out, dragging along John McCain, the third diver who was going to be Dr. Joel Hedgpeth’s post doc and assistant. Paul and I immediately began collecting shells and coral chunks.

PAUL: We had never been in the tropics so they were all new to us. We were loading them into our T shirts that we had taken off as makeshift collecting bags and eventually even into bathing suits.

GORDON: Every once in awhile, I would look at the compass to make sure we were headed to shore, note the seagrass direction, and adjust as necessary. Finally, after we had been swimming along humping the shirts full of treasures, Paul was poking me and indicating that we are in only three feet of water.

Well, we agreed to go up to see where we were and to

re-orient as necessary. We were about 25-50 yards offshore and we were dead center; that is, directly offshore of the center pylon. Now I'd like to tell you it was good navigation, but it was probably more by good luck than skill.

PAUL: We had “argued” all the way in because, though Gordon had the compass, I was looking at the ripple marks and seagrass. We were writing notes to each other in the stand and the poor John was just being towed along. Also, as we were getting near shore, we were lunging along with our shirts full of shells and corals, writing notes and arrows in the sand, and looking at the ripple marks. But we compromised and it was a miracle that we got there.

GORDON: It would be hard to say it was good planning but there we were and all Mother said was “Get on the #**!@! boat”.

PAUL: Though grudgingly, he told us that our time was the fastest in three years to be that close to dead on the marker and almost nobody does that.

PETER: And you didn't come up at any point?

GORDON: No, because we were too interested in all the shells, coral and other critters. Besides, we couldn't have come up; we were carrying too much weight. The next day (Day 4), we got called into the office of the Commanding Officer for the whole Navy Diving School. We figured that this could be interesting but had no clue why we were summoned. Well, it was interesting. The Captain said, “I see you guys want to go to the Antarctic to scuba dive and I see that you need

to be certified by the Navy that you're qualified to scuba dive there. You're obviously qualified divers. You have also been a royal pain in the ass for my instructors and disruptive of the class. So I'm signing your authorization, Now, you've got 20 minutes to get off my base and I don't want to ever see you again".

GORDON: Aye, Aye Captain, we are gone!

PETER: Well, they'd seen plenty from the navigation that you knew how to dive and look after yourself in the water?

GORDON: They knew we could dive.

PAUL: We were the fastest and most accurate, even with our shirts full of shells and corals. However, by the sixth day in Florida, they were starting to smell pretty ripe. There were more adventures that we probably should skip over, but we had a good time in Florida, the Bahamas and Blue Ridge Mountains.

Another adventure leading up to the actual program on the Ice was that we had to have a Navy physical which was a big deal. We had to go to the Naval Hospital in Oakland California to get it from real Navy doctors.

PETER: To do research there, you had to go through a Navy approval process whereas now it's a National Science Foundation approval process. So that's really interesting, how you were colliding head on with the Navy environment to get approval.

GORDON: Well, it was pretty interesting in a lot of ways, even in the medicals. For example, I have a bunch of fillings and the dentist told me, "You can't be authorized to dive." "Why not?" I

asked in my least offensive mode. "Well, you have fillings. You could get air in behind them and it could cause excruciating pain, etc. as you ascend" was his response. I allowed as how "I'd done about a thousand dives to this point and never had a problem with it. And besides I'm civilian; I am not trying to be a Navy diver." He had to write down that I have these fillings and the Navy would not be responsible for fixing them if I had a problem and I could not require that the Navy compensate me for any needed dental work. But he did not indicate (in writing) that I was not qualified to dive. That was just one example.

Another one. They gave us these long (>20 page) multiple choice psychological tests that asked basically the same questions about five different ways; i.e., Are you gay? Would you kill people when you get mad? Do you fly off the handle? Are you suicidal? Do you suffer from depression? They ask you this in about a hundred different ways. I figured out the repetitive inanity after about three pages so I just filled in the choices randomly. The psychologist noted immediately that I was not taking this test seriously but decided that I was mentally fit enough to be a diving scientist and qualified me. I suspect that, were I in the Navy, his response might not have been so charitable but I think they just wanted to get us out of their hair.

Paul has this fear of needles. He is probably not afraid of anything else that I know of but if I pointed a needle at him (maybe even now), he'd faint. A couple of times when they took blood samples, I had to tell the technician to wait a minute. Before you touch him with that needle, let me get a hold of him so he doesn't hurt himself when he faints.

PAUL: I fainted.

GORDON: He did faint but he didn't hit the floor.

PAUL: Let’s go into the first season then. After the all of this certification, orientation and everything else, we were ready to go in on the early October flights to McMurdo. Gordon was in a class in Hawaii so he couldn't go down with me right away. I went in on an early-mid September flight (fondly known as “WinFly”). By the time I got there, Jerry Kooyman who I helped in 1963 and 1964 was there with his diving suit. I had all of the diving, sampling, and cage gear to organize and get working.

PETER: Jerry had wintered over?

PAUL: No. He was just doing his work; he was there almost every year. He and I were on the ice. We got a hole in where you could see the bottom.

PETER: At Cape Armitage?

PAUL: Yes, it was right near that wall.

PETER: The wall meaning the one they call Dayton's Wall now at Cape Armitage.

PAUL: I did not name it. It was late winter and there are a few hours of dark periods in early September. For some reason, there was a lot of brash ice under the annual ice sheet so it was dark underwater.

Jerry and I found Verne Peckham's old underwater lights that needed a big generator for power. We lowered them down maybe 20 feet below the hole so we wouldn't get electrocuted. We cranked up the

lights that were hanging maybe 20 feet below the hole and dove in.

Having the extra light made me feel a little better on my first dive. I went down first and Jerry was going to follow me. My first experience and lasting impression was that, of course, the cold hits you in the face. And also that by the time you get through the hole (the first minute of a dive), you're already starting to get the cold. But, the most impressive thing was that you could see everything for long distances in all directions. It was one of those moments in your life that just stays with you. I swam out from underneath the hole and, with the lights below me shining down, I could hang there under the ice and look around to marvel at and integrate in great detail, the beauty of the place. It's just hard to imagine water that clear. We eventually measured visibility in one case and found it was about over nine hundred foot laterally where the snow cover was minimal and the ice was about 8 feet thick.

GORDON: The first dive I made in Antarctica was off Cape Armitage. We had cut a hole the old fashioned way with a chain saw (more on this later) and pulled our fish house over it. We looked down and could clearly see bottom with the starfish, nemertean worms, sea anemones, and sponges. So we hung a weighted rope in the hole along with Verne’s lights but, in our excitement, neglected to measure the water depth. However, in retrospect, our experience diving other places in the world biased our judgment and we assumed it could not be very deep if we could see bottom that clearly. On this, my first dive, I preceded Paul on descent. By 100 feet, the bottom was still a ways off. By 150 feet on my depth gauge, it was not looking a lot closer. By 175 feet, we both

decided that the bottom was still too far off so we went back. After the dive, we measured the depth at 230 feet! THAT was a real eye-opener for me and we learned to be careful to measure the depth before we suited up when we went to new areas.

PAUL: So, to continue with my first dive with Jerry Kooyman, I could clearly see the bottom down there. The lights were illuminating it but I could see that, once my eyes got used to the dark, I didn't need the lights. I just went rolling down to the bottom, because it was right there.

When I looked up for Jerry, he was framed by those lights and he seemed about an inch long. I realized that I didn't have a depth gauge. I had thought we were going to be working at 30 or 40 feet like we did everything in Puget Sound and Friday Harbor.

PETER: The depth gauges were the wrist mounted ones?

PAUL: I had none. Gordon brought it down. It was a little thing where the bubble went around and you had to have a magnifying glass to read it. It was hopeless. So we did not have good depth gauges the first year. We figured out the depths once we started working, with a combination of actual measurement with a weighted line and, as the season wore on, by our observations of the benthic epifaunal zonation due to the anchor ice formation and uplift.

OK, I need to make a confession now that my diving career is over. I've never had a class in my life. I've never been certified by PADI, NAUI, YMCA, or anyone else. I didn't know about

dive tables or other depth related rules but I just knew that it was a deep dive. Kooyman wasn't coming down - he was still an inch long up there- so maybe that should have been a clue.

We came back up and we discussed how deep it was. Finally, we put a line down and we realized that it was pretty deep.

PETER: And that dive was just for you to check out the equipment and setting?

PAUL: Yes, just to see what it was like. It just blew me away because it was so beautiful. I was really stoked and I made a few more dives with Jerry. I think we put another hole in where the big structure is in above a wall. For the first dives, to be safe and to be sure we could come back to the location directly under the hole in the ice, we put a marker on the bottom. Basically a weight from which we ran lines all over the place. However these lines disturbed the benthic habitat that, even from the beginning, we could tell was physically stable and not disturbed. For the first few dives, we also used Verne's lights but the long cord provided too much drag and it tore up the bottom. Besides, we did not need the lights to see. So we quit using the lights and the cords.

PETER: Were these open-air holes, or were they inside a hut?

PAUL: It was inside a hut. That was my first dive and it's got to be still one of the most wonderful things I've ever done. Gordon came down pretty quickly after that.

PETER: Gordon, how long after were you there?

GORDON: I was there in early October, just a few

days after Paul. I got home from Hawaii, in mid September and, by the beginning of October, I was on my way to the Antarctic. The first time I jumped in that cold water, my body did not appreciate going from 78°F water to 29°F water; it was a real eye opener, to say the very least. It was a case of instant involuntary cryptorchidism that then lasted for three months of diving under the ice.

PETER: Did you have to do anything at McMurdo when you arrived, like sign-in or go through any training or anything?

PAUL: Everybody knew me because I had wintered over not too long before and I had been there for 15 months. No, we didn't have any special sign-in or orientation beyond what everyone had.

PETER: You just instantly started.

PAUL: We just got off the truck, found the equipment and start putting it together. That self confidence came from the experience of my wintering over. Once we made a few dives, it did not take long for us to realize that the seal-fish-polychaete food chain question wasn't going to work. It was a bad question.

But, the star fish were eating sponges all over the place. At that point, I was already working on the starfish paper with Chuck Birkeland at University of Washington where we laid out all of the foraging dynamics of Puget Sound starfish. It was the first paper like that, so we were into starfish predator-prey dynamics. Starfish were doing things we could see, measure and count, so we switched pretty fast I think.

PETER: Because you didn't see that much going on,

right?

PAUL: The fish could care less about our cages. I don't remember if we put them down there or not at that point; that is, early in the 1967 program. But I think we did put a couple in pretty early because they were covered with a blanket for awhile to make the cave look like a safe haven for fish but keep the seals out at the same time. But we gave up the seal exclusion/fish refuge hypothesis early when we realized that there was a lot of deep diving associated with a task that was unlikely to provide meaningful data. Also, I realized that most of the fish I had seen the seals eat were the Antarctic cod, *Dissostichus mawsoni*, which is found in deep water - much deeper than we could dive - and that the seals were not much preying on the small fish we saw in <150 feet.

The deep diving reminds me of a fairly interesting story. As I noted earlier, I had never been formally trained in scuba diving but Gordon had been, so he knew about dive tables and those gas laws. We realized we had to make two dives a day to get things done, so right from the beginning we were doing repetitive dives. I had never heard of the repetitive dive table.

PETER: Not even the Navy tables?

Paul: No. I started diving in 1954 when I was 13.

PETER: But in Florida at the Navy Diving School, of course you heard of it.

GORDON: No. They didn't bring it up. They couldn't even get Boyle’s law right. I am sure that we would have been

exposed to the repetitive dive tables had we survived longer at the Dive School.

PAUL: So I got mad at Gordon who was giving me a hard time as he tried to tell me that the second dive had to be shorter and/or shallower. Especially as the first dive was sometimes 150 feet or more. Because I did not expect that the diving would be so deep when I was planning the program, it was something we never thought about (even if I had known about it).

PETER: Well, were you looking at a repetitive dive table and determining the required surface interval?

GORDON: No. In the beginning, I just knew that at 90 feet you had about 30 or 35 minutes bottom time. And I remembered a few of the other combinations down to about 130 feet.

PETER: That was for a single dive. But what did you do for multiple dives?

GORDON: After I realized we were going to be doing repetitive dives and to depth, we had this “discussion”. Some of our lab neighbors might say it was an argument that was pretty loud but it didn't turn violent.

PAUL: Yes, like “What do you mean I can't make the same deep and long duration dive twice in one day???”

GORDON: Anyway. We searched around at the Biology Lab at McMurdo, and by a fluke, we found the Navy dive tables. There it was in the Navy diving manual which, in those days, was THE bible for scuba divers. I probably did say “I told you so!” We suspected

that the manual may have been left over from one of the previous scientists who were diving and had the foresight to bring it with them.

PETER: So then, based on the depth of your first dive and duration, you would use the tables and determine how long you needed to remain in the surface between the dives and how deep you could go for how long on the next dive?

GORDON: Right.

PETER: So you tried to make your second dive shallower than your first?

GORDON: I think most of the time we tried to do that and we generally succeeded. Also, because the ice was eight feet thick, we could stop under the ice and put our hand on the ice, which put us at effectively our first recompression stop. Especially on the second dive, we'd stay there for 10 minutes or so though it sometimes was really hard to stay because we were really cold by that time. It was not uncommon at the end of the second dive, and occasionally even at the end of an especially deep first dive, to get out of the water suffering from mild hypothermia. Teeth chattering and shivering hard.

PETER: That was just on your air supply. You didn't put a reserve tank under the ice at the hole?

PAUL: No. We had plenty of air as we had double tanks filled to 3000 psi.

PETER: Double 72s?

GORDON: Yes and in the subsequent years we had some double 80s. For many dives, we probably could have done it just

on single tanks and still had air left over.

PAUL: The first year, especially, we didn't have tank pressure gauges so we didn't know what was in the tank while we were diving.

PETER: What about J valves?

PAUL: Those things always get flipped, when you're doing something so we did not trust them either.

PETER: Did you check them underwater to make sure they were up?

GORDON: It's hard to do that when you have all that wet suit rubber on your arms and torso.

One of the things you notice right away is that mobility and agility is very much impeded with the weights, tanks, wet suit rubber, sampling gear, camera, etc. on you plus we had awkward gloves or mitts with limited dexterity.

PETER: How much weight were you carrying?

PAUL: We both had eight to ten pounds which was considerably less than we used in Washington, and we had much more wet suit in the Antarctic.

PETER: Because the tanks weighed a lot?

PAUL: No, we were so deep that the suits compressed. It was so much easier with just eight to ten pounds. Once we figured out the repetitive dive tables, we kept track of our time. I did have a watch but I couldn't see it during the dive because it was dark down there. When we got back to the surface, we would record the elapsed time and

we would cheat on the depth by assuming either that we were slightly deeper on same-depth dives or longer at deeper portions of variable depth dives. We would calculate our tables as if we'd been at deeper depth and a stop longer.

So we were doubly conservative for the first year. We got the “Bendomatic” the second year (the SOS Dive Meter by Healthways and Scubapro). It was a relatively primitive “computer” that was supposed to account for time and depth, plus changes in depth, and emulate the Navy Repetitive Dive Tables. As it turned out, they were not very accurate or precise, and the error could be in either direction; i.e., too conservative or not conservative enough. There was apparently not much predictability as to which way any particular “Bendomatic” would register, at least in temperate waters. Well, they worked for us in the cold Antarctic. We could see when the needle was in the red even at depth, and ours were conservative in the cold when we compared them to the dive tables. They had us coming up sooner, and then stopping and staying at our stops longer than we needed to. We really got good at the tables after a while because we used them all the time. I had them so well memorized I could see where the equations changed with different variable depth profiles. We were careful and never got the “bends”, at least, not so as we noticed it.

PETER: Well managed.

GORDON: We had to be, because the nearest recompression chamber was in Christchurch, New Zealand, about 2400 miles away. And in those days it was flying on Lockheed Super

Constellations which flew at less than 300 miles an hour and typically about 20,000 foot altitude. It would have been a very long trip for someone suffering from the bends.

PETER: Plus going up in the air having the bends or decompression sickness would only make the problem much worse.

GORDON: It would not be a good day!

PAUL: We knew that.

GORDON: We would also have to be concerned that we might not even get out, as weather was always a major concern for flights to/from McMurdo in the 1960s. Finally, there might not be a plane on the Ice and it may have been a day or two before we even got the ride to New Zealand.

PETER: That's why you were conservative, because you knew it would be hell to pay.

PAUL: We were very careful.

The other thing were the adventures with the scientific support contractor. At this point, when Gordon and I went down, the scientific support was being provided by a commercial contractor Northstar, instead of Stanford University who lost that contract and Northstar, an outfit in Minnesota, took over. They didn't know anything about either scientific diving or the Antarctic in general. The examples were numerous and would have been funny, except that they really impacted our program. Some examples. We asked for a dive watch. I remember a whole bunch of communications with National Science Foundation (NSF) and Northstar that we wanted a dive watch. North Star

finally sent us an alarm clock in a bottle. Another example. We wanted neoprene glue so we could make repairs to our wet suits. This stuff was expensive and we were graduate students so we didn't have money for the things like this glue that Northstar was supposed to give us anyway.

We counted on them to get us our expensive glue to repair our wet suits. It was called “Black Magic”. Northstar wanted the details on this Black Magic. There was all this correspondence with a lot of stupid questions (from my perspective) such as, “How much do you want?” ”Give us two cans in case we lose one”. Finally, being really generous, they sent us three big (quart size!) cans of Black Magic automobile putty for sealing windshields. At first, we couldn't figure out what this was for. Finally I made the connection. So we had to get our wet suit glue from other places. Gordon, do you want to go to filling the tanks hassle.

GORDON: Okay. First, I'd like to mention two things about which Paul will not blow his own horn. So I will because they are central to central to the function, scientific success, and overall safety record of how well it's gone over the past 45+years.

The first you have already heard a little about. As you go along in this dialog, we could come across as a couple of reckless cowboys. But, based on his prior experience on the Ice, Paul was very insistent about safety without imposing a lot of the silly, time and dollar-wasting CYA regulations and bureaucracy that are in place today. Because we were in a harsh and unforgiving cold environment, it would

be real easy to get seriously injured or die from one thing or another. Paul and colleagues in other OAE interviews have described a number of incidents from the late 1950s and early 1960s that formed the basis for his safety regime. He harped on being careful about the ice conditions, especially how thick it was. Just because it looked like it was thick ice was not a good criterion; it might only be two inches of ice with snow blown over it. There were a lot of things like that that he made me aware of.

Another one that proved to be critical was that, when you're driving one of those heavy, tracked Nodwell vehicles, you drive and operate the controls with your right hand. You keep the left hand on the door handle all the time because, if anything goes wrong and the Nodwell starts to break through the ice, you have about three seconds to get out of it.

PAUL: One fell through the ice in 1975.

GORDON: With one of our colleagues in it. He didn't make it out and I had to inform his parents of the tragedy. So it's a good lesson. It was unfortunately reinforced but Paul was very adamant about that and many other safety aspects of the program.

The second point is the scientific approach that led to this program. This whole technical program started in1964 when Paul first went down there. If you go look at the previous dialog when Paul was describing looking through the hole in the ice and making observations, you get some sense of the way he thinks. All of us make similar natural history observations but it takes a special scientific mind

to go the next step(s) and ask “Well, what does that mean? What's the question here? More important, what's the hypothesis to test here and, how am I going to test it given the circumstances in which I have to do this research?”

The whole program has been going on from 1964 to now; long enough that we can think of it as Paul’s academic family of his graduate students, and their graduate students, and maybe graduate student’s graduate students. Are you up to four generations yet?

PAUL: I don't know. I don't think so.

GORDON: The beginning of this program in 1963-64, was a graduate student, Paul, who really thought very intuitively about the ecology of this environment, and how things worked. Paul observed and then he asked the right (mostly) questions. He also asked a lot of questions that we couldn't answer at the time, but that he and students started to address in later research as they learned more. To be fair, he (and we) asked a lot of questions that, afterwards we could say were dumb ones!

There are lots of scientists who can *repeat* what Paul and his colleagues did. But there aren't many who can look at an ecological situation and initiate ground (or ice)-breaking research by asking themselves, “What's the next question? What's the next hypothesis or experiment here?” And then following through with a practical approach to test the hypothesis.

That may be the lead-in for Paul to describe the change in the program in the first few weeks of the first year. He made the

observations very quickly that the original proposed program wasn't going to work. So what else can we do? What's the other question here?

PETER: Before we leave safety behind, there's something else we should discuss. Diving there under the ice. You can get away from the hole and you can't see it after a while, especially when you pass the critical refraction angle for light underwater. You weren't diving tethered so you were diving free under eight feet of ice with a three-four foot hole as your only escape. Did you have any general practices such as you guys would just not go that are far away from the hole?

GORDON: We had two or three things to keep us oriented and within reach of the hole in an emergency. First, if you look up you can see the hole. It appears much like a can light in a pale white ceiling in a ballroom. You can be a long way from the vertical axis of the hole at depth and still see it, especially in the deeper dives. Second, most of the places we were diving were on a steep slope so we always knew which way was shallower or deeper. We were very confident of where we were relative to the hole.

PETER: You weren't on a flat featureless plain is what you're saying.

GORDON: Correct. And there were several big white sponges and other biological landmarks as well as airplane fuselages, construction debris and other junk that we could see over a long distance. Finally, we had a ladder in the hole and most of the time we had a rope with a weight hanging from the ladder. We could see that

as well. Often, we could hang stuff on the rope if we didn't want to go all the way back to the surface and that provided additional landmarks.

PAUL: We had the ladder and rope down all the time when we worked from our dive huts and we used the rope with a weight whenever we worked off the ice in remote locations.

And the other thing, you can see in the some of the YouTube videos that people post from diving at that Cape Armitage site, there is a big, heavy metal plate with another heavy plate mounted on a pipe a couple feet long. This thing is sitting at about 75 ft depth and it marks the second hole that Jerry Kooyman and I put in after we found the bottom too deep in the first dive in 1967. I had the Navy make that because I knew from when I wintered over that the bloom came in very fast and was very thick. I was worried that the bloom could come in almost overnight and just be soup and might even happen while we were down. I didn't want to get lost. So we ran parachute cords from that structure all over the place and most of those little lines are still there almost 50 years later.

PETER: Like cave diving with secured guide lines.

PAUL: Right. Even though we could see, we were careful.

PETER: That's very careful.

PAUL: There were a couple of situations where we couldn't see the hole as we came up or swam towards where we thought it was. Sometimes, there would be a lot of brash ice under the sea ice and it would fill in the hole so it was not visible without the rope. Also,

when you are in shallow water or just a few feet under the ice, you are below the critical angle for the refractive index of light in water and the hole “disappears”. Then we needed the “down line” or we would have to swim to deeper water so the hole “reappeared”.

But what we learned in a month was that we knew that bottom so well, that we knew where that hole was. We didn't need those parachute cords and we never used them again.

GORDON: We were always aware, even subconsciously, where the hole was. Another anecdote and to emphasize the importance of knowing the location of the hole. The third time I went to McMurdo (1974), I took some of Paul's students down. I was his “project manager” while he was finishing teaching at SIO. I told both of them (John Oliver and Jeff Rude) that “When you go in that hole the first time, you're going to be worthless as a scientist for the first dive or two, because all you're going to do is look over your shoulder to make sure you know where that hole is.” Of course, both gave me the usual diver macho of “Oh, no, I've been diving for years and in all sorts of situations, so I will be fine.” Well, all of the first dive they spent looking over their shoulder to make sure they knew where the hole was. But, after a couple of dives, they were comfortable and worked like pros.

PETER: There were no alternative exits because you were not near a place where Weddell seals were hanging out and getting in and out of the water?

Gordon: No, most of the time we were remote from the seal breathing and haul-out holes. Even when they were close by, the

holes were often too small for us to use, especially if they were just being used by the seals for breathing; those holes might have an exit diameter of <12 inches. Even the haul-out holes were barely big enough for us to use especially with a double scuba rig and all the other crap we had on.

PAUL: We should probably talk about cutting the holes. We were short on holes the first years. Later when we had the drill rig, the place was like Swiss cheese. We had holes everywhere. In those early days, I learned how to cut a hole with a chain saw. The year that I wintered over, there was 15- 16 feet of ice. You cut out 100 pound blocks with a chain saw until the chain saw goes through the bottom and the hole floods. You still have a plug of ice that might be a foot or more thick. You have the 25 foot pipe with the big railroad chisel on the end of it that you spend up to a day and a half, hammering on the ice to knock that bottom out of the hole. You really can't stop because it is cold and the hole will freeze.

Then all the brash ice comes up and you have another almost day of cleaning it out, one net scoopful at a time. So, in the beginning, making a hole was really hard work. When I wintered over, I acquired by a "midnight requisition" a bunch of 60-40 dynamite. I had watched loggers in Oregon using it when I was 7-8 years old. I knew how to insert the cap and fuse. I took it way out on the ice in the dark winter and, with a little practice, learned how to blast a hole, but it still was a fair amount of work. The blasted ice still had to shoveled out of the hole along with the brash ice. I used the chain saw a little bit to make the hole square. So the holes were hard to come by.

There's a whole progression of the efficiency of hole-cutting. When we took the Navy diving school in 1967, one of the Navy guys asked how I made the holes and I told him. He suggested I use detonation cord (det cord). He said that, instead of pushing the blasting cap into the block of dynamite, wrap the det cord around the dynamite and then lead the cord away from the dynamite. Then you can put the package down the hole where it will not kill you if it goes off. Then tape the cap to the det cord and if it goes off you lose a finger but not your life. He showed me how to do that. That just made it so much safer and easier. But he also got us to use C-4, a plastic explosive, instead of 60-40, which I think he said was faster and really wonderful. At this point we just asked for it as though we were always issued huge boxes of C-4! We used that C-4 for the first two years (1967 and 1968). I went back to 60-40 dynamite because the C-4 just makes this awful mess. The water is all black and the ice around it is black.

GORDON: The black ring shows up underwater and makes the hole even more distinctive against the rest of the ice cover.

PETER: But you just had to open up one hole with C-4 to use for a season's work?

PAUL: No, we made lots of holes all over the place in McMurdo Sound. In those days, they were good with the helicopters that we used to get to remote sites. The pilots were mostly from Vietnam and they were used to explosives on board. We would just carry our det cord, hell box, and dynamite in a case on the chopper and have the caps in our pocket in the same chopper. We would drill a hole with the

Sipre drill (a hand auger), which is slow process, even in just a few feet of ice. --

GORDON: We had a gas-fired power head for the drill.

PAUL: Yes, but it didn't work too well much of the time. So we would have to turn the drill by hand. Then we would tape two or three blocks of C-4 to a bamboo stake and put it down the hole so the bottom block was just a little bit underneath the hole so some of the ice would be blown back up the hole.

We blew the holes and then worked for an hour or two cleaning the blasted ice and brash ice from the hole. If we were at a remote location such as Cape Evans or Cape Royds, we'd set up our tent and make our dives. We'd try to get in a second dive before the pickup. If we were at a site closer to McMurdo that we were going to use regularly, we pulled a hut over the hole so we had shelter and a working platform. So we went all over. And that was a lot of work but a hell of a lot of fun.

PETER: Would that hole stay open? I know they freeze up but could you get in it the next day when you came back?

PAUL: Yes.

GORDON: We came back to some of them even a week later. We might have to blow out two feet of ice or break it out with a chisel. After a couple of weeks, we generally had to repeat the drill-blast-scoop routine especially early in the season when it was cold.

Though we did not specify it so far, the diving season

was from about late September-early October which was the first WinFly to about mid-December when the dense plankton blooms moved in and visibility would go to almost zero in an hour to day as Paul mentioned earlier.

PETER: Was your working area along Ross Island up to Cape Evans from Cape Armitage?

PAUL: And Cape Bird, and Cape Royds.

PETER: Cape Bird… you had dives up there?

PAUL: Yes. And Horseshoe Bay behind Cape Royds. And then New Harbor in the '70s.

PETER: In the '70s. I was talking about early on.

PAUL: Gordon and I went out into the Daley Islands. And that was scary, because there was so much brash ice in the hole. It could choke you and you couldn't get out. So we only made a couple of dives there.

GORDON: Yes, really, that was spooky, because there was 10 to 15 feet of this brash ice in the hole. We could not “swim” our way through it, at least not quickly.

PETER: Are you talking about the brash ice floating underneath the sea ice ceiling getting into the hole? It was that thick?

GORDON: Well, it was even thicker than that away from the hole we blasted.

PAUL: Probably 30 feet thick.

GORDON: Because of the blast, it was kind of an inverted cone under the hole but it was still 10 to 15 feet there, and that

was after a couple hours of both of us scooping it out of the hole. We could get in and out of the hole, but we realized that if anything went wrong with a regulator, we wouldn't get through that brash ice in time; i.e., a minute or two.

PAUL: I just wanted to see what the benthic community looked like that far from the sea ice edge.

GORDON: It was a neat idea.

PAUL: The point is, we were getting around, making holes all over the place, but with a lot of effort.

GORDON: One of the criteria for making a hole in the ice was that we get a good picture of the blast against the spectacular scenery. I think I have a picture of almost every blast we made.

PAUL: There's a bunch of things that I wanted to talk about such as the routine of diving, the fact that our gloves were marginal, and we would come up from the dives cold. I don't like to emphasize that the cold because people think you're trying to be heroic or brave or we are trying to out-macho them. But we were cold, especially in the hands. The fingers in the gloves, especially the first year, would wear and we would sometimes have bare fingers. We would try and seal them with neoprene glue that we would borrow from people because the auto putty didn't work.

And we only had the one set of gloves. They would ride up and expose our wrists sometimes. For the first dives, we literally couldn't use our hands to grip the rungs and climb up the ladder.

PETER: Your hands were clubs, right?

PAUL: We used our elbows to crawl up the ladder and into the hut. We'd take our gloves off with our teeth and put our hands in hot water. Sometimes, we would still have the tanks on our backs because we couldn't get them off very easily. They had those funny loops and buckles, not the flip buckles that we got later.

I remember countless times where we're both sitting there with our tanks on our backs, our hands frozen and we would put them in hot water.

GORDON: It hurts!

PAUL: It really hurts! We'd be sitting there with tears running down our face because our hands hurt so much and, at the same time, we'd be excited. "Did you see that? Did you see that the patch of yellow sponges, the starfish doing such and such?" It was so damned exciting and fun that the cold hands were utterly irrelevant. It was so exciting that we just routinely did this ritual. It was like amputating our hand for a while and then finally the tingling quit. We'd be able to take the tank off and do those belt things, get out of our wet suits and then we poured the hot water over ourselves. Sometimes we had a stove on which we might have some water heating up and we just stand there and pour some water over ourselves trying to get warm. It felt good but it didn't do much for the core temperature.

GORDON: There was not much thermal transfer from just pouring hot water over us.

PAUL: I have a picture I think that Gordon took to show people how the body responds to cold. Remember we had three ¼

inch layers on our torso and only one on our legs and butt. Early in the season when it was really cold, the picture shows my torso is sort of normal color but my butt and legs were bright red. Later in the season, our bodies learned not to lose the body heat. So later in the season, peripheral blood vessels constricted as soon as we went in the water. It's a pretty interesting physiological adaptation in that my legs would be blue because my body wasn't losing as much body heat. Then we found two tubs that weren't tied down outside the USARP Chalet.

GORDON: Just to amplify the evolution of the warming process. We first tried just going to our office and sitting in front of a heater. Marginal success and took too long. Then we took showers at the barracks but that also was marginal and we got hassled for using too much water which had to be made on site from melted snow. Then we went to the hot water rinse Paul just described while standing in front of a roaring diesel-fired furnace in the hut. Then EUREKA! The USARP to the rescue.

PETER: USARP is the United States Antarctic Research Program and the Chalet was the scientific administration building.

GORDON: Yes. We realized the thermal transfer wasn't working very well by just pouring water over ourselves or even with showers. On the second dive every day we started out cold. Often, especially on deep dives, we'd come out of the water slightly hypothermic. Besides being somewhat unsafe, being really cold is not a very good way to get anything done, intellectually. One day, Paul and I

were driving by the USARP Chalet where they were having a party that we weren't invited to (or we chose to ignore). We noticed that, on the veranda, there are two galvanized tubs that are about four feet long, a foot and a half wide, and foot and a half deep. They were both full of beer and ice. In the same instant, we both said “Do you see what I see??” We backed the truck up, opened the tailgate, slid them in, and took off. We took them back to our fish house (which is what we called our dive huts) and we now had two bath tubs.

PAUL: We also kept the beer.

GORDON: Yes, we couldn't just leave the beer outside or it would freeze so we stored it on the floor where the temperature was just above freezing. We would fill those tubs up with hot water as soon as we got out of the water. That worked well as the thermal transfer was much more efficient. And we met the USARP Chief Scientist requirement that we not take such long showers in the barracks though I suspect that we actually used more water (10-15 gallons each) with these “bathtubs”.

PAUL: Life was good.

GORDON: There is a picture of us in these tubs in the National Geographic in October 1968. That's the only picture that made it into National Geographic, of probably a thousand pictures I took for one of the National Geographic photographers. He came to McMurdo to do a National Geographi story about the Life on the Ice. He wasn't a diver but he wanted to get some underwater pictures so he gave me the film. I took the pictures with the agreement that he would give me copies of the

slides.

He did give me those slides though not without some serious hassle and threatening letters from me to the president of National Geographic. Of all the pictures we gave him, some of which were really good underwater pictures, that's the only one that made it into the story.

And we didn't even take that one.

PAUL: We did have something to keep our hands warm. There's some correspondence that I'll give you with a guy named Tinkelpaugh who made thermal cream. It was calcium chloride in glycerin. Calcium chloride reacts exothermically with water, so we put a greasy wad of calcium chloride in our hands in those old horrible gloves. When they leaked, which they did right away, the water reacted with calcium chloride. It would burn our palm so we sort of moved it around to distribute the heat.

It did work but everything got covered with the oily film of glycerin. And it just wasn't worth it as it messed up the camera lens, mask lens, and anything else we touched.

PETER: You didn't try glove development like gluing cork fabric on the outside of your gloves or anything like that?

GORDON: In the second year, we started to use different kinds of gloves. We worked with five-finger gloves under a big mitt and variations with long sleeves.

PETER: So you were constantly working on it.

PAUL: We didn't the first year though because we didn't expect the gloves to wear out. And we had nothing but Black

Magic “auto putty” to work with for repairs or new construction.

PETER: So then you came prepared the second time with lots of options?

PAUL: Yes. But our hands were still cold.

GORDON: Even when we got the Unisuit dry suit system in 1974 and the Diving Unlimited dry suits in 1984, my hands were still cold.

PETER: It is still a problem to this day.

PAUL: I still have all sorts of problems with arthritis from those dives that first year. Underwater photography was an example of the challenges the cold hands caused. Gordon had a better camera, but I borrowed an old Nikonos I that had these little tiny knobs that you had to adjust for both f-stop and focus. It's dark down there and I couldn't really see what I was looking at anyway. But I have this tiny knob to try to control with these fat cold fingers that had no feeling. Also, we had flash bulbs that we had to change with a big glove. After some practice, I got pretty fast with the flash bulb and could change that faster than the strobe would be recharged by far. But we were still using fat, cold, unfeeling fingers to adjust knobs, push the button to take a picture, reach someplace to pull out a single flash bulb from the neoprene holder, stick the bulb back into the reflector thing and all the while trying to keep your eye on your transect to remember where you were along it. So taking the pictures meant we had to have fingers on the gloves, not big mitts.

So we just had to put up with cold fingers and hands. It

just went with the business.

PETER: You mentioned working in the dark. So you didn't use any underwater lights?

PAUL: Yes, we did. We did give up the lights that were powered by a surface generator and went to hand-held dive lights. We had those great big metal things.

GORDON: Allen lamps. Because they were aluminum and we had to hang onto them, they would suck out whatever warmth we had in our hands.

PAUL: Literally caused me frostbite. We put neoprene on the handles to reduce heat loss. We did use them to signal each other if we wanted the other guy to come over and look at something real cool. We used these lights as often as we could but they ate those D cell batteries, ten of them at a time, and usually within three to five dives at best.

GORDON: The Navy and Northstar got tired of seeing us coming because they knew we were going to ask for another case of batteries.

We had some of the more modern lights later but, even at that in that cold water, they just wear out the batteries quickly. And the last time I was down there (1984), I had a re-chargeable light that worked well, but a charge lasted for only for a dive or two at best. I had the same problem with batteries for my SubSea camera strobes and those batteries became obsolete just prior to 1984.

PETER: Certain batteries don't work well in the cold.

PAUL: Maybe we should go through some of the diving adventures. Do you want to tell him about John McCain? The poor guy who had no clue what was going on at Navy Diving School while Gordon and I were collecting corals. He was tied off behind us and we had look after him on our last compass dive. He was a postdoctoral student for Dr. Joel Hedgpeth.

PETER: From what institution?

GORDON: He would have been at Oregon State University at the time.

He got down to McMurdo where he was qualified as a diver but, because he was by himself, he couldn't go in the water unless he could find some buddies. We knew Joel pretty well and so we agreed with Joel and John that, so long as John was not in our way and we didn't have to look after him, he could dive with us, because he wasn't going to be diving very often. He was collecting sea spiders, so that really did not interfere with what we were doing and he did not need to go far from the hole.

There were at least two incidents with John that were entertaining for us, though not so much for him. We didn't want him wandering around and getting lost or anything, and Joel was a little concerned about having his post doc in the water more or less alone. So Joel would let John dive with us but John had a rope tied to him and back to Joel in the dive hut.

PAUL: John was well tethered!

GORDON: They worked up the signal system. When

John pulled on the rope once, Joel was to let out more line. Pull it on twice, retrieve line slowly. Pull three times, drag as hard and fast you can. Joel got bored quickly so he tied the line off before John was on the bottom. There is John about three feet off the bottom pulling once on the line for more slack.

PAUL: Joel is out of the dive house wandering around to survey the scenery or whatever, having tied the line off on something.

GORDON: John is trying to do some collecting so he's tugging on the line and nothing is happening.

PAUL: We did our whole dive and here's this poor guy going round in circles pulling on the line and trying to get to the bottom.

GORDON: We couldn't figure out what was going on.

PETER: Poor guy.

GORDON: Incident two. As we already described, when we came out of the hole after a dive, we were darn cold and we just wanted to get out of the water and into a hot tub. When I would come up the ladder, I would take off my weight belt and throw it up on the floor. I told John two or three times, "Don't leave your mask on the floor near the hole!" He'd come up and leave the mask there. And I was afraid that one day, Paul or I would toss a weight belt on it. After all, the last thing I was worried about was his mask. So sure enough, one day, I just tossed my weight belt and "CRUNCH – SHATTER". There went his mask. Well, you couldn't buy a mask in the Antarctic at whatever they call that store down there (the PX). They just did not have a scuba shop there!

PETER: You didn't have dive tenders so while you're in the hole, you had to get your weight belt up and out. You didn't slip out of your tank and hand it to somebody so they could hoist it out. You got out of the water wearing your tank and most of the rest of your gear?

PAUL: We would often slip out of the tank because it would be close to neutrally buoyant anyway. The first one out would then retrieve the tanks so the second guy could climb out without his weight belt or tank.

PETER: First person out was the “tender” of sorts?

GORDON: We would switch off. Paul would go up first the first time. I'd go up first the second time.

PAUL: Meanwhile, John had been flailing for something like 40 minutes. He was first through the hole and he was sitting there with his mask on the floor. Gordon comes up, tosses weight belt, and ”CRASH”. And then I came up to find the weight belt on his crunched mask, and John sitting there on this stool, sobbing.

GORDON: It took him a week to get another mask.

PETER: Did you come to McMurdo with spare dive gear? You must have.

GORDON: I had another mask, but due to very poor vision, I had my lenses glued into the face plate. They were prescription so they were no good for anybody else.

PAUL: We never had close call in our diving that was serious.

GORDON: No, but we did have an exciting one.

That's a story we have to tell about Jimmy Stewart.

PAUL: The second year (1968) we got a dive tender of sorts. It was Chuck Galt, another graduate student at University of Washington. After taking his training at Scripps with Jimmy Stewart in the summer of 1968, Chuck came down to be our tender. The reason we were adamant that we needed a tender came from an outdoor dive in Horseshoe Bay in 1967. I really wanted to see Horseshoe Bay because it looked like a neat place. We had flown in and put up our Scott tent which is just a tent with the single pole in the middle. We didn't tie it down because, although it was really cold, there was no wind and it seemed to be OK. We spread it out and had a Coleman stove inside. It was really cold outside so we cranked up the stove and heated up the Scott tent. The Scott tent has two layers of material so there is a “dead air” space. Around door, these two layers can be tied off so it is actually pretty airtight and retains heat. The tent and stove were working fine. We blasted our hole, and went diving.

We did a long dive and I remember coming up really cold, with the hand problems and everything. They were really like stones. When I came up, there was just this gale blowing snow that hit me in the face. It just nailed me and my mask immediately had ice all over it so I couldn't see. The seawater froze before it could run off, it was that cold in the open air!

I took my mask off and then my eyelids froze and I was all messed up. I scraped some of the ice off and I was looking through little holes. I still have frostbite scar from around my cheeks where my

cheeks got frost-bitten, because I wanted to keep my eyes open.

Plus we had those horrible straps on those old tanks that you put a loop in it so you can pull it to undo them and get out of the tank. Except that they were chunks of ice so I couldn’t undo the darn things. And Gordon is down there cold. I'm cold, my hands don't work, I can't see, I can't get my tanks or weight belt off. I can't really find my weight belt.

Finally, I crawled out to find the next obstacle to warmth! The tent had blown over. Luckily it hadn't blown away because we had stuff in it but it was over on the side. Gordon popped up and I yelled at him, “Leave your mask on”. So he left his mask on but he couldn't see through the ice that built up on it. We both struggled out of the hole and helped each other out of the tanks and weight belt. The wet suits were, at this point, cracking all over the place from water freezing on, in and under the neoprene outer layers. We struggled into that bloody tent and got it upright. I was trying to start the stove, and Gordon was holding the two doors open. He's sitting between those two loops, and holding them open so I could see. I was pumping and pumping that white gas and putting my matches in the burners. It was just not working. I kept pumping and choking the damned thing with no flame at all. I didn't understand, until I dropped a match that was still burning, that the white gas wasn't vaporizing because it was so cold but that it was coming out as a liquid and pooling in the stove and floor. So now there's a puddle of white gas on fire and our clothes and things are inside the tent. Our hands don't work. Gordon may still have had his

mask on though maybe he took his mask off when we got out of the wind. Anyway, somehow the gas finally vaporized and here was this ball of fire on the floor of the stove and Gordon was still holding the door open so I could see. I scooped up the stove with its pool of burning gas and tossed it at the door. I hit the opening, fortunately, and it went out. As I recall, it blew up. We were standing there having survived a fire bomb and now no stove, but at least we still had shelter.

GORDON: No heat though.

PAUL: It was just one of those winds that comes off right near Cape Royds. It was just awful as we thought we were going to be there forever, because "What could fly in that wind?" We had no stove and thus no heat except body heat. And darn little of that. We had frozen K rations (K-rats) for food. We were able to get out of our diving gear and get dressed so we were no longer freezing to death. Eventually the helicopter came and it all worked out. But, that incident made us aware that we needed a tender.

PETER: Are you saying the practice then was to go out in the field without taking along survival gear and camping gear?

PAUL: No. We had that. I knew that from my earlier winter-over program. We did have bags of survival gear.

PETER: So if you had to camp --

PAUL: We would have survived for several days. Maybe we would have been hungry and probably cold but we would have survived. We had sleeping bags. I knew not to have them in the tent because one of my friends did have a tent burn up once with the sleeping

bags in it. All our survival gear was somewhere close by but outside the tent. So we weren't going to die.

GORDON: No, much as we felt like we were going to for awhile that day.

PAUL: We weren't comfortable and there was a real lesson in survival and the need for additional help.

PETER: That really illustrates what it's like to dive under the ice in Antarctic. Underwater it's perfectly still and calm and then you surface into these roaring conditions. Everyone wonders how you can dive underwater, it's so cold. They think that's the life-threatening issue for Antarctic diving. But, it's what you come out into after a dive that can be the biggest problem.

GORDON: Yes. There were lots of times when going underwater was much nicer than being outside when we were diving at remote spots. The air temperature, even when there was no wind was often 30^{o}F and occasionally up to 60^{o}F colder than the water at 28^{o}F.

PAUL: Almost every time.

GORDON: It's good to have a tender, but it's even better to have a tender who pays attention. We had at least one incident, in addition to the John McCain–Joel Hedgepeth one described earlier, to illustrate this. We dove one time at the junction of the annual sea ice and the permanent ice shelf, right in front of the New Zealand station near McMurdo. At the junction, the annual ice is all broken and fractured, piled up, and there are lots of ice floes in a jumbled mess. We wanted to see if we could get to the bottom and see what it was like this far from the

usual edge of the annual sea ice.

One of the Navy support guys came over to be our tender. We gave him the basic signals which were the same as we described for the dives with John. He was going to feed the rope to us and haul us back if we needed it. We were also going to have the rope down so that we could follow it back if we had to. We were basically cave diving.

Well, it worked out fine, except that he didn't hang on to his end of the rope!

PAUL: He walked off to take pictures or something.

GORDON: The rope wasn't tied to anything; he just looped it over the door handle of the truck.

PAUL: Our descent and thus ascent had been back and forth because the ice was folded and broken. So we are counting on following the rope back. We were pulling on it gently as we came up until we are holding the end of the rope in our hands and we are not at the surface yet. That was a serious OSOD (Oh shit oh dear) moment!

PETER: That is so bad.

GORDON: Fortunately, we were most of the way back and we could see the ambient light so, we had some idea where to go to get out. I don't know what rank he was, but I bet he never had his ass reamed like he had it that time. I was pretty close to just throwing him in the water and leaving him there but Paul saved his life.

PAUL: Do you remember the time in 1967 when the BBC film crew showed up. They wanted us to get dressed in our wet suits

and ride a snow machine over to the dive hut while they filmed. This silly entrance rather than just go to the Hut Point dive house in a pickup or Nodwell like we always did, and get dressed and things. We just wouldn't do it. We told them that they could film us in our normal routine and that was all we were going to do. They got really obnoxious and even reported us to the USARP manager but he stood behind us for once. Then I saw them having some other people, dressed up in USARP garb and pretending to be in a wet suit. They came driving over on the snow machine to our dive hut with scuba tanks on their backs.

PETER: On snowmobiles? Like divers drove snowmobiles with scuba tanks on their back? That's ludicrous.

PAUL: I thought, that's okay, we're not doing it. But by this time, they'd been really obnoxious and we didn't like them. In fact, Gordon almost bonked one of them later.

GORDON: They said that they wanted to come out and film us diving. I had to point out that we're going in the water, so unless they were coming in with us, they weren't going do see us diving per se. And unless they were Navy certified, we were not going to let them dive with us or in our dive sites. And even if they were certified, we were not going to dive with them. But they wanted to film us going in and coming out of the hole at a minimum.

We agreed with a couple of stipulations. First, you stay the hell out of our way. We'll knock you in the hole if you're in our way. When we toss the tanks over our head to put them on or we turn around with a tank on and it hits you, it could break something and knock you in

the water. If that happens, it's going to be your problem, not ours. Second, don't leave your camera gear anywhere on the floor, especially near the hole when we come back up. We've already broken somebody else's mask this season because they did not heed that warning.

They pretty much stayed out of the way and we didn't get to knock anybody flat with our gear though, of course, it wouldn't have been intentional. We managed to get in the water without too much hassle from the cameraman and director. However, when we were coming out, they weren't quite ready but they had left the door open with an awful wind so that the light would be better. I came out first at the end of a long, deep, and cold dive that included a 10 minute decompression stop under the ice.

PAUL: The hut door was open. The wind was howling through the house so it was cold!

GORDON: I came up and started to get my weight belt and tank off so I could get out of the water. Here is the director in my face saying, “Sorry mate, we were not ready so would you go back down and come up again so we can record it”.

I will leave my next five or six words to your imagination but he got the point that there wasn't any way I was going to do that. He needed to get out of my way or he was going to get a weight belt, tanks, and flippers in the middle of his camera.

PAUL: We were cold and our hands didn't work.

PETER: You were in a critical moment, you had to get out.

GORDON: I was coming out this of the hole right now whether he was in the way or not.

PETER: Every dive you stayed to your thermal limit because you were trying to get work done.

GORDON: Right and that meant we were always cold when we got back to the hole. So I just flung the weight belt out and got out. He wanted to be able to get Paul coming up. I told him he better get him the first time, because I'm a nice guy compared to what he'll say and do to you if you ask him to go back down. He got his film and we never saw them again.

PETER: Did the footage ever appear on TV?

PAUL: I saw it in 1968 when I went to my first-ever Scientific Committee for Antarctic Research (SCAR) meeting. When they played it, they introduced it as New Zealand divers because we refused to sign waivers. And here come the two clowns roaring by on the snow machine, with the scuba tanks on. Then there's Gordon looking up, ripping his mask off.

PETER: So you don't know if it ever made it on TV. You just saw it at a SCAR meeting.

PAUL: I don't know if it ever aired. What other things did we want to cover here?

GORDON: Well, another amusing anecdote. Most of the helicopter pilots were a duty rotation that included Viet Nam followed by the Antarctic. This was in the Vietnam War. On one trip we were going out to Cape Evans by helo. We were going to blow holes and all

that, and so we had all the survival gear plus C-4, caps and det cord. This was the very first flight in the Antarctic for this pilot so he was not going to carry explosive and caps on the same trip. There were going to be two separate trips and there was no changing his mind, so a second helo followed us up there.

Anyway, this was his first flight in the Antarctic. He came in and hovered about one inch above the ice where he held it. He told us we could get out here while he hovered. We were trying to tell him put it down on the ice and we'll take our stuff out. Even the crew chief and pilot of the other chopper said put it down on the ice; it's safe. The pilot was adamant that he did not know if it was safe as he had not had the ice thickness checked out and it's a safety issue. It's in their book.

Everybody was trying to tell him that the ice is eight-foot thick and not a problem. Finally, I pointed out that he flew in on a Starlifter (C-141) which is several hundred times heavier than a helo and they landed that on the same ice sheet. What we're asking you to do is put this little helicopter on that same ice. But he didn't. We unloaded that plane while he hovered for about 10 minutes one inch off the ice and in the same place. It was a pain in the ass because the rotor blew so much wind and snow around. As an aside, the other pilot did just land on the ice to drop off the rest of the explosives and miscellaneous gear. We did our dive and the same pilot came back to pick us up. This time, "Boom", right on the ice with no hesitation. Obviously, he had a discussion with somebody who made it clear that, first, this hovering jazz was not safe when unloading civilians and their

gear, and, second, he didn't need to worry about the ice being safe to land on.

PAUL: Let’s talk a little bit about the challenges of filling our tanks. We were used to the routine of filling our tanks at Friday Harbor, so we knew about using and maintaining the compressors, main tank bank, filters, etc. At McMurdo we had to do all that and even build and repair the system. The compressor was in the Butler Building where Northstar had all their field support stuff. We would take turns sitting up there after every dive for an hour to two and a half hours to fill our tanks for the next day’s dives. We would use four sets of double 72s in a day. I'd be taking notes or writing in my dive logs or something to make use of the time. Occasionally we would make some midnight requisitions of candy bars and other essentials that were otherwise a real pain to get from Northstar in the regular requisition mode. So a good chunk of our life was sitting there with our compressor running. It was okay in that we could sort of relax while the other person was running around getting things ready for the next dive or preserving specimens we collected.

The system worked pretty well. But at the end of the first summer, the compressor was really slowing down because it was just old and over-used. Also, I didn't realize it at first, but we were coming up with our mouth’s having a sort of pasty feeling. It turned out that there was oil getting into the compressed air. Predictably, I think I got pneumonia from that oil. Now I knew if I turned myself in at the medical center with pneumonia, I'd be sent home. That would be the end

of the program and Gordon couldn't dive alone, at least not officially. So I was really having trouble. Pneumonia is scary, you can't breathe and you can't lie down. You have to sit up straight because your lungs are full of that stuff.

Gordon just went out and did the things by himself with me occasionally as a tender at the surface. I think you also had somebody else helping you but not diving.

PETER: You weren't changing compressor filters.

PAUL: There weren't any. That was the problem which once again demonstrated how poorly prepared Northstar was to handle support for a diving program.

Then Gordon got a mild form of pneumonia or something similar. I finished the season diving alone. There were not that many dives and it was safe enough except when the plankton bloom came in. I knew where the hole was from the bottom topography which we knew very well by that time.

But I had trouble on my last dive hitting the hole as I was coming up through the bloom. The plankton bloom reduced visibility from a couple of hundred feet to virtually zero just under the ice. I would come up in the brash ice and plankton, feel around for the hole, go back down, and try again. There didn't seem to be much current but there was enough to move me out of location just a little. It took several tries to find the hole so that was our last dive that season.

GORDON: I think I was down there wondering, “Where the hell is he?” It is always scarier to be on the surface tending

than it is to be diving, especially when you know what could be going wrong.

PAUL: Yes, but then we made a big pitch to the NSF to get another compressor and change the filters.

So in the summer as we were ending our program, NSF sent the dive guy from UCLA down to review the compressor situation. He said the filters were pretty old, and these guys are using it without … blah, blah, blah, ……. So he put on some more filters and declared all well.

Well, when we got there at the beginning of the second season, we started the compressor but the other filters just killed the compressor and blew the valves or a piston ring and it didn't work anymore. So now we're there, in early September on a WinFly and knowing that would be nothing coming in for another month.

It turned out that the fire department had a compressor for filling their self contained breathing apparatus (SCBA) and they volunteered to let us use it. So we'd go over and sit in the fire department every day for about five hours. They weren't that fond of us after awhile with that compressor disturbing what little rest they could get. I think they actually let us take the compressor back over to the Butler Building.

GORDON: Yes, because it wasn't the big compressor like we had so it was much more portable and it was smaller because they fill their little bottles and they did not need to do that very often.

PETER: And you were filling to 1200 or 1600 PSI in

your double 72s or 80s?

GORDON: 3,000 PSI. We would just run them all the way up.

PETER: And the tanks were doubles in four sets, that's why it took so long. It was a lot of air and time to pump it.

PAUL: We didn't want to run out of air.

GORDON: Actually, we were effectively filling about one of the doubles, maybe one and a little bit because we'd come back with those tanks still holding 1200 - 1400 PSI.

PETER: You didn't run them down?

GORDON: We wouldn't even come close on most dives; it was too cold and/or deep to stay long enough.

I did run one down one time in 1984. By that time, we had DUI dry suits. I went into 30 feet of water and spent three and a half hours there. I essentially emptied the tanks to about 400-500PSI because time was not a limiting factor and cold was much less of a problem in those suits.

I did have another instance of emptying a tank, largely due to my own negligence. As background, Jimmy Stewart had told us in the beginning of the program that if we had any problem and you have to dump your weight belt, “DUMP IT!” He did not want us to be like many of the casualties he had seen where he found the body and they still have on their weight belt. His mantra was “Dump your weight belt and I'll get it for you or get you another one”.

Well, I ran out of air one time in 1974 at about a hundred

feet on a dive near Turtle Rock. As we drove there from McMurdo, my tank was bouncing around in the back of the pickup and I think the valve cracked open slightly. Most of the air was gone but there was still enough to start the dive. I didn't know that it was low though because that's probably the only time in my career I didn't check my pressure gauge.

PETER: Before the start of the dive

GORDON: Right. So a few minutes into the dive I thought, “Man this tank sucks hard.” Well, there was a reason for that which became obvious as soon as I looked at the pressure gauge! Anyway I dumped my weight belt and ascended fast, blowing air the whole way from my Unisuit and my lungs. I came shooting through the hole with Jimmy standing right there. I almost hit him in the face. After I quit bouncing around, I told him, “Remember you said if I dumped a weight belt, you'd go get it. Well, my weight belt is down there.” God bless him, Jimmy put on his gear and went and got my weight belt.

PAUL: Maybe I could talk about the value to our diving program of my wintering over in 1963-64 and learning how to scour and scrounge, and take care of ourselves, and then you could augment it. Most of the scientists knew how to take care of themselves and they did not have to depend on the support people. All the support was provided at cost plus and thus a financial benefit for the contractor. They would have even bathed you if you let them, because that meant they would have to hire six, seven, or eight more people to bathe scientists and then they got cost plus on all of that. Eventually they successfully

forced the scientists to be utterly dependent on their super expensive support.

When I wintered over in 1963, it was back in the era that John Dearborn and Jack Littlepage and those guys were talking about when the Navy basically ignored us. They told us to stay out of the dump, but they had a weasel (a small tracked vehicle) with tracks the same size as we used on our Polecat. Art DeVries and I went down to the dump and he showed me how to get a track off the weasel, and nobody cared. I used at least one on the Polecat that winter and we used the other one the next summer. It was important to anticipate things and not worry about stupid rules about not going into the dump. Also when I figured out how to do the blasting in the middle of the winter, I went up to the isolated building and just took the dynamite, caps and fuse, and took them way out on the ice where I learned and practiced blowing holes in the ice. As a 7-8 year old, I had watched loggers blow stumps. I knew how to get the cap into the dynamite and run the fuse into the cap and use more sticks of dynamite. Figuring out how to apply that technique to ice on my own saved God knows how many miserable days of chain saw cutting! The point is we became self-reliant. If we wanted something done, we did it ourselves, especially when we ran into resistance from the support folks, whether it was the USN, Northstar, Stanford, or later contractors. When the chain saw broke, I figured that it's a simple engine so I sat there and broke it down, figured out how it worked, and fixed it.

We had to be prepared to be totally self-reliant and I

think that helped when we came back. When bad things happened, I would not wring my hands and complain, and send electronic teletypes [this was in the days long before the Internet or satellite telephones] and beg or rant for this or that. In the meantime, we would go looking around to see where we could find a compressor (the fire hall), how to deal with immersion heaters to keep the holes open wide enough, or “midnight requisition” enough steaks and other goodies so we could eat in the fish house.

PETER: Coming back refers to what season?

PAUL: I was there for 15 months in 1963 and 1964. And then we came back in 1967. Gordon, what was your impression.

GORDON: I would second that it was very useful experience in just learning how to fend for yourself. For most of us in graduate school, there wasn't a course in self-reliance in the field. You either learned or you don't learn that, but you learned it on your own. The place you learned it was programs like this where, you can't go to the local Home Depot to get whatever it is you needed. You have to figure out where you're going to find it in this place. In a place as big as McMurdo, it was probably there somewhere; it was just a matter of finding it. I'll have to say that my relationship with a lot of the Navy folks was a whole lot better than it was with the Northstar for the most part. Many, though not all, the Navy folks really wanted to help. As far as they were concerned, we were a great diversion if they could help us. It meant they didn't have to do their normal routine job for a day or whatever it took to help us and they were quite happy to break the

boredom.

So when I went looking for something, very often they would tell me, “Well, it's here or why don't you go over and talk to the guys in the maintenance department or go over to the photo lab. Somebody will have it.” I got my camera fixed half a dozen times down at the photo lab. Those guys were great.

The SeaBees (Navy Construction Battalion) could be helpful when they wanted to be. For example, when I got there in 1974 in charge of the program while Paul was home teaching, Paul told me that that they stored fish houses (or dive huts) near the SeaBee building. He told me we need two or three of those on the Ice at specific locations, so go get it done. I went over to the SeaBee building to talk with the lieutenant commander who was in charge. He was on the same plane as I was coming in so he didn't know anything about what was going on in his unit at McMurdo. So he said, “Go talk to the chief [petty officer who is really in charge] and make sure you mention a bottle of whiskey in there somewhere”. I found the chief and told him that we needed three of these fish houses just like that one out behind the shop here and there was a bottle of whiskey in it somewhere. He wanted to know when we needed them. “Oh, sometime in the next few days, because we have to get stuff together.” That was about 3 o'clock in the afternoon. The next morning or possibly two days later, he's behind me in the mess hall, taps me on the shoulder and says, “Your fish house is ready.”

GORDON: Okay. I went out there and looked and by God, those SeaBees had a fish house in one night, brightly painted and

good as new and the rest over the next couple of days. The chief got three bottles of whiskey. I wouldn't have drunk that whiskey. That stuff was awful.

We had the SeaBees do a number of things like that. We asked them to clear snow from an area at Winter Quarters Bay. We wanted the four foot snow cover removed from an area about 100’ X 100’ so the light would get through, and we could see to dive without lights. The next morning we came to Winter Quarters Bay to an amazing sight. The SeaBee with his D-8 bulldozer ended up being out there all night and he'd cleared at least a football field. He didn't have anything else to do or it was better than anything else he was scheduled to do.

PETER: You had a lot of light underwater as a result.

GORDON: Man, did we ever! We also had a snow berm 15 - 20 feet high all the way around the fish house. That turned out to be a bit of a problem because that much snow is heavy when piled up in a berm. It pushes the ice down so the water comes up through the top of the hole and cracks in the ice and runs under the fish house. Then it freezes so that the 12” X 12” runners for the fish house (which is essentially a house on a sled) are frozen into the ice and they don't break out easily.

PAUL: You have to chain saw them out – it takes all day.

I would like to get back to the science which was why we were there. I talked earlier about the question for ecological “stability” which at the time was a popular concept in ecology. Based on my

previous experience at McMurdo from just looking down to the bottom through the holes, I had the idea that this was a habitat that was structured around biological interactions rather than physical forces. One of the first things we saw was the biological zonation. From the shore to about 20-30 foot depth, the bottom was a sheet of ice or bare rock or gravel. The next 20 feet or so had ephemeral animals or starfish, and from 40 to about 60 foot depth, there was *Clavularia*, a small stoloniferan, and more hydroids and other cnidarians (sea anemones). The density of these species increased to a depth of about 100 feet or about 30 meters. Relatively suddenly at that depth many species of sponges, some very large, show up sitting on a mat of sponge spicules – in a few deep areas the spicule matt was half a meter thick. We speculated and later demonstrated that the zonation was caused by a decrease in the amount of anchor ice as depth increases and the anchor ice stops at about 30 meters. The anchor ice forms on the ground and, when it gets to a mass that has more buoyancy than the weight of the rocks or whatever organisms are holding it down, the anchor ice mat with any critters in the ice crystal matrix floats up to the underside of the ice sheet. That's a disturbance that's not predictable in a short time/space scale, but is predictable in the longer term; hence the zonation. And we saw this occur all the time, so there really was no doubt about the importance of this disturbance. I now know that this zonation related to anchor ice formation is common around the Antarctic continent

This sort of wrecked my reason for working in the Antarctic. Remember that my idea was that the marine habitat was

extremely stable and predictable but now we see overwhelming anchor ice disturbance that is not predictable and varies in intensity along the depth gradient to 30 meters. It was apparent that the stable area started at around 30 meters depth.

That's why we had to work deep. I really did want to focus on that physically stable zone, where there wasn't this unpredictable anchor ice disturbance. Also, the dominance of sponges rather than fish and polychaetes made me realize we needed to change the focus to working with the sponges and the community variables that influenced them.

The other day, we talked about John Dearborn going down all by himself, getting off the plane, and seeing only white snow and ice. He was trying to do a thesis in a habitat that had last been sampled by the British 50 years before John got there. But nobody, including the British naturalists, had ever looked at any biological relationships. They just collected samples through the ice using grabs and dredges, took them home as preserved specimen and sent them off to different specialists to be identified taxonomically.

Dearborn had to sample all over the place with his grabs by himself, which I think is really just a tremendously remarkable bit of hard work for a single person. But still, there's no way he could identify any real ecological relationships because he was still relying on a grab dropped blindly to bring up his samples. It was a huge effort and I very deeply respect him, but the ecology he could do was to pick the samples and describe what he collected with regard to depth, location, time, etc.

So his thesis has maps of sponge spicule mat which was really what he was sampling along with some star fish, anemones, some sponges, and other critters. He didn't have many of the huge sponges or many of the other epifauna that were large and sometimes in low density. These were the critters that we saw as soon as we got in.

When we first went down to their depth, our reactions were “My God, it's a forest of sponges, and they're beautiful colors and shapes and there a lot of them and they are probably all different species and WOW!!!” Neither of us had ever worked with sponges before. We didn't know anything about sponges. We didn't know the names of starfish although Dearborn helped immediately. We knew almost nothing about the taxonomy of the sponge food web. John Dearborn had given me almost 100 slides of animals from his thesis work, but he was looking at the small animals in the sponge spicule mat rather than the big ones we were looking at. For this reason we ended up giving the sponges descriptive common names based on some obvious feature; basketball sponge, volcano sponge, finger sponge, staghorn sponge, red or green sponge. These names allowed us to collect data and leave the taxonomic work until later.

We had a good idea of the starfish names from Dearborn, but we did make a mistake with the *Perknaster*. It turned out that the mistake was a good one because I split it into two species and it turned out they were the same species. I learned from the mistake.

Almost everything else was an unknown species and even genus or family in most cases. It's really frustrating when you just

don't know what you're doing and you're still trying to study all these ecological interactions of competition, feeding behavior, predation rates, growth rates, etc. We thought we were going to be able to detect and measure all these growth rates and we didn't. We quickly realized the bad news was that we knew nothing about the ecological relationships of the benthic community we were immersed in, but the good news was that no one else did either and we were going to be the pioneers in this effort if we could just ask the right questions and collect the right data.

It was the first year that Cadet Hand, a sea anemone expert from Bodega Marine Lab in California, came down to McMurdo as a VIP. He was going to be able to go to South Pole Station and have all these boondoggles. But when he stopped in the BioLab to see what we were doing and found us with all these sea anemones and hydroids that we could not even begin to identify, he just got right into what we were doing and basically he never left our lab until he went home. Some of the great wisdom of George Llano came to play early in our efforts to identify the species we worked with. George had spent a great deal of effort and money to buy complete sets of the Discovery Reports and Terra Nova Expedition Reports for McMurdo. These many volumes included the original descriptions of many of the animals we had to identify. With the limited library we had, Cadet identified most of the anemones and hydroids that I probably would never have learned. His visit was serendipity and it made a big difference to us.

We did okay in the long term because we eventually got names for the animals from experts all over the world. But while we

were there, we didn't know the scientific names and we just used these colloquial names. Just another example of learning to improvise in the pursuit of science.

GORDON: We didn't make too many taxonomic errors by lumping or splitting species. At least for the significant sponges, starfish, and all sorts of things, our names held up pretty well and could be matched with the correct scientific names later provided by the experts.

PETER: Names you used in publications were in line with the Antarctic scientific expedition reports and it's obvious that you had researched them. Some of those names were found in reference material in the library there, from my understanding.

PAUL: Well, we had all the Discovery and Terra Nova reports as well as the Libbie Hyman series and numerous other scientific expedition reports. This is the great advantage to having a library, even a small library unlike my own Scripps Institution. But with the sponges, you have to spend a lifetime looking at spicules to identify them and even then there is still controversy amongst the various experts.

We used the old Antarctic expedition reports for other stuff but the pictures they had were usually of preserved specimens and almost useless, and the keys were really hard to use.

There was at least one mistake I made by lumping two really different species as Volcano sponge. When you lump and make an error, you can't always correct it. If you split, which we did with *Perknaster*, then you're okay because the data are originally separated and

can be simply combined. With the *Perknaster*, it was lucky because they looked so different that I argued with Dearborn about it. But he was very stubborn that my two species were just morphs of the same species. The little ones are about maybe six to ten inches in diameter at the most with thin hard little arms. We knew they would eat everything, because we were keeping track of the diets for all the starfish.

Then there's this great big honker which is about 18 inches in diameter, fat and slimy.

GORDON: Ugly!

PAUL: Yes. They really look like different starfish with totally different size, shape and feel and it was slimy to boot. However, we had tagged a bunch of starfish of numerous species. This included tagging the little *Perknaster*. One of those little ones that I tagged crawled onto a *Mycale* sponge which is the competitive space-dominant sponge. Once the little tagged *Perknaster* found the *Mycale*, the little *Perknaster* turned into the big *Perknaster* as it switched from having a wide diet to being an absolute specialist eating only the *Mycale* sponge.

That is one of the few cases in the literature even today where you have that nice Type 3 functional response really working well. This refers to a situation in which a generalized predator encountering a common prey item develops a search image and specializes on that prey species. It is important because it serves to “regulate” a prey species that is increasing and possibly taking over the environment, which *Mycale* definitely could do.

So our splitting the taxonomy turned out good because we had separate data sets to define this prey response switch.

PETER: I want to go back a little to learn about how you switched from fish eating worms, to looking at something different. You guys are down there together. Gordon, you're there to help Paul who is there to study fish eating worms. You start out doing that and then switch. Did you guys talk about that a lot? You talked about anchor ice formation forming the benthic structure. Did you come up from dives and discuss things and then you go look at that on the next dive?

GORDON: There was a lot of that discussion in the bathtubs after the dive as we warmed up, at supper, in the lab, at the officers' wardroom, everywhere. A lot of it comes down to how we were each making these observations and more important, how we thought about them. I was generally thinking like a naturalist and observing in the moment. Paul was making observations but combining the naturalist's perspective with his questioning mind and asking, "Why is that so or why is that happening?" So he would often be the one that posed that question or hypothesis, and then there would be a lot of discussion about how to test it. After the dives, sitting in our office; just BSing about what we had done that day, and what was coming out of it and what do we think about that. But I would have to say, even though we were about the same age and same level in graduate school, this was sort of like being in a professor-student relationship. I learned a lot as a student.

PETER: But you applied what you knew from your research in intertidal and subtidal environments and course work, and you

could start trying to construct a picture of what you were seeing?

GORDON: Yes. And we were learning by ourselves. This was a real learning experience *in situ* without any sort of class. We had to figure things out for ourselves or the program would have been a failure. There were very few people at McMurdo that we could use as mentors in marine ecology or ecological processes of any kind. There was very little outside support, especially for that first year even with Cadet Hand and Joel Hedgpeth there.

PAUL: Joel was a very nice gentleman, but not much help to us.

GORDON: He was a distraction because he loved to talk and he was in the next office to ours. Really, it was the two of us. There were other scientists around but there weren't any marine biologists so there wasn't anybody really getting in and doing what we were doing.

PETER: Well, how soon did you realize there were no sessile organisms shallower than 45 feet, and ask why are these big sponges only below a hundred feet? That's not just a prediction from sticking your hand in the water. How did you guys go about re-structuring your program and knowing what to do next?

GORDON: Paul and I had and have a slightly different perspective but several observations came together at the same time. As soon as you get in the water and you look around, you see that in 35 or 40 feet of water or less, there's nothing up there; it's mostly abiotic and all gravel. That was kind of odd because it was apparent from the lack of gouges and trenches in the bottom that the area was not getting scraped

clean by moving broken sea ice. There were no big scour marks or anything such as I later observed at Prudhoe Bay in the Arctic.

So, we asked ourselves, “Where is that barren area coming from?” Not very long after that, we noticed on the rope hanging down the ladder from our hole in the ice that there was frazzle ice up to a meter in diameter around the top and that it tapered down so that, at about 90 feet (30 meters or so), the rope was bare. Well, that raised another interesting question, “What is causing the ice to form like that?” and “Does that have anything to do with the zonation?”

Then one day I found and photographed a 50 pound steel dredge that one of the scientists had been using down there. But it is not on the bottom where you would expect to find something that heavy. Instead it's frozen into the underside of the sea ice. The anchor ice had formed around it much as we had observed anchor ice forming around sponges and other epibenthos in the shallower areas until the ice buoyancy overcame the weight of the dredge whereupon the ice lifted it up from the bottom, and it was frozen into the underside of the ice. We spent a lot of time under the ice shelf looking around, especially during our decompression stop, and we noticed that there were little bits of sponge, starfish, sea urchins and other critters frozen into the underside of the ice sheet. How did they get there? They obviously didn't swim!!

So I think all these observations came together when, eventually, we saw a mat anchor ice float up with critters in it. It happened when we were swimming over it, so we probably provided just enough energy to break the ice loose from the bottom. In fact, it scared

the hell out of me when it happened another time in shallow water. The bottom started lifting up. Paul saw the same thing happen in deeper water?

PAUL: Yes. What was happening was pretty obvious.

GORDON: It was pretty clear, yes. Just a further note. As soon as we began to understand this process and the consequences, Paul recalled an article by one of the early explorer/scientists (Frank Debenham and Swithinbank) in the McMurdo region who observed marine benthic invertebrates, especially sponges, on the sea ice surface and well up the slopes of Observation Hill just south of McMurdo Base. They had speculated about how that happened. I don't recall their speculation but it was way off base. The anchor ice phenomenon provided a plausible and likely explanation.

PAUL: It was really the second year when it became very apparent that nothing worked as I had hypothesized in the stable food web. All the cages were exactly as we left them and essentially nothing had changed inside or outside them. That was disappointing. Remember that I had been working with starfish and their predator/prey roles in Washington and Gordon had been working with the nudibranchs and all of their difficult biology – he was a very good observer. We could deal with the predators, food webs, and other cool life-history phenomena. We did that reflexively, because we were doing it so intensively for our dissertations in Washington.

At McMurdo, we were doing much the same kind of

predator/prey inclusion/exclusion caging that I was doing in Washington (and that was the vogue of the day, especially amongst marine intertidal ecologists). In the first year at McMurdo, we were separating the predators from the prey to see how much the prey grew (exclusion cages), or putting predators in with the prey to get feeding rates and growth rates of the predators (inclusion cages). I put brooding starfish in cages so I could see how far the brooding had gone the next year. We did all that the first year with the expectation that we would be describing and measuring community dynamics, population interactions, competition, invasion, and all the wonderful things that a marine ecologist gets excited about.

But when we came back the second year, very little had changed. The one exception was the *Mycale* sponge, which settled on things inside a cage and grew all the way through the cage and over the critters in the cage killing those underneath the *Mycale*.

On the other hand, there were starfish that didn't move for three years. We have pictures showing the same starfish in the same place for extended periods. There was the brooding *Diplasterias* that I had in the cage. I knew from looking at them, that they go through a stage with little eggs to big eggs to baby star fish and this takes brooding for at least three years. I knew that these things were sitting there for three years. But I put one in the cage and it was the early stage (little eggs). I looked at it quite carefully, and it hadn't gone from the little sort of eggs with legs starting to come out into the star fish. They were still little eggs with legs starting to come out looking exactly as it had the year

before.

So those things might sit and not feed for five or six years while brooding their babies.

So when we came back in the second year (1968), we were confronted with a real potential research disaster because it appeared nothing had worked let alone worked as we expected.

PETER: That time scale is not good for producing dissertation research or publications.

PAUL: No. And we both were, at that point, really happy that we had our independent theses that were coming along, so our lives and our careers didn't depend on the results of the Antarctic program. But we were proud, persistent, and stubborn and I really wanted to figure out how that system worked.

Plus, for me, this was the most important challenge of my career; the best sort of field judgment of what to do with a surprise.

The first surprise (or maybe better described as a disappointment) was when the fish didn't eat the worms. Though I expected them to, it was so obvious when they didn’t that we knew that line of experiments was not going to work.

But here with the starfish and sponges we could get food web data and that's all we could get. We would have to infer how much the predators eat of those sponges and things.

So at the beginning of the second season, we knew their diets, but nothing else. How could we actually evaluate the community roles of the predators? How much of their prey do they eat per year?

What impact does this have on the prey populations? How can you really understand the integration of a community with diet data? How much can one realistically extract about ecosystem dynamics and functional roles from food webs.

We realized that we had to construct this information by indirect means and ecosystem approaches then being developed by John Teal and others. Fortunately we had read his papers and those of the Odum school so we had a ground work for evaluating their impacts via energetics. But we had no energetic data let alone process information. We need to evaluate the amount of energy channeled into each predator population in a year and relate that to the energy that was available to them. So we needed metabolic rates, growth rates and energy into reproduction that should add up to a rough estimate of the amount of potential energy going through the predator population. I knew how to do respiration rates from my winter with Curly's fish, so I could do respiration rates pretty well. They're hard to do with starfish or anything, because the subject can get "psychotic" and exhibit abnormally high rates. We avoided stressing the asteroids (starfish) by carefully sliding each one separately into a glass jar on the bottom and letting it sit there with the cap screwed on. If we saw them running around in the jar, we didn't use them. We used the ones that were happy to sit there in the jar, and then we analyzed the oxygen with the old Winkler procedures I knew so well from wintering over – indeed, the set ups from 1964 were just where I had left them in the store room, so we moved easily into that. We were lucky with gonad indices because we were there on the WinFly

and the animals had not spawned yet. We were also able to use data that John Pearse had collected. These animals can put a significant amount of potential energy into the lipid rich gonads.

We still had to calculate and convert energy in a population into individual growth rates. In the first year, people had not been successful tagging sea stars, and we had tried using floy tags in Washington but learned that they pull them out. So we were successful using monofilament line going through an asteroid leg with the tag on the line. This worked. And so we had growth rates when returned.

We calculated how much energy the population of each predator was using, but we still needed to regress these data over the data on potential energy available to them from the sponges. This involves a great deal of work collecting and estimating biomass of the prey species from photo transects. For this we needed to calculate the biomass (eventually the calories) of the sponges from linear measurements of sponges as seen in the hundreds of transect photographs. Then, given the diet data, we could calculate the impact for most of the predators on each prey species. Then, this is where Bob Paine showed up and really helped a lot. Bob was my advisor doing a sabbatical in New Zealand and he came down as a VIP. Importantly he was a real expert on calorimetry, and he knew a bunch of problems we were going to run into.

We had to bring up all the sponges and get all the sizes, relying on measurements that we could see in the photographs from a vertical shot above the sponges. We measured that dimension and the weight of actual sponges we collected in the field. This was a guide to

length-weight relationships for sponges that you could measure from photographs. We did this with several other species as well. Thus we had size frequencies of all those species that we felt were critical to the predator-prey energetic model in our study area. Eventually we got the caloric values measured back in Seattle when my wife spent a great deal of time carefully running the machine. Eventually we could integrate all these data and construct via the back doorway what these sea stars were doing to the habitat.

I remember sitting there reading John Teal's paper thinking that this was kind of hard and it was. I don't think anybody has ever done that since. Now ecosystem people don't talk to food web people who don't talk to functional people. I think that paper still stands out in my mind as maybe one of my proudest achievements, and that I think is pretty neat. And I'm proud of it.

GORDON: Well, along with that core science Paul just described, we made a lot of natural history observations that nobody else had done or could have done without *in situ* observations that we could make in a diving program. So anything we discovered was new. Much of the basic natural history and observable ecology of the benthic community around McMurdo Sound was, to a large extent, described initially by the work we were doing. We made a lot of ancillary observations and discoveries. We found a sessile ctenophore that was probably about six inches tall (*Lyrocteis flavopallidus*). We looked at it for a long time and decided it was a cross between a sea anemone and rabbit. There was no other way to describe its appearance, especially as

neither one of us was aware that there was such a thing as a sessile ctenophore.

PAUL: We had a huge fight over it

GORDON: Yes. We had all kinds of hypotheses (beside the anemone-rabbit cross). Finally one day I saw it with the tentacles out and realized those were ctenophore tentacles.

In the BioLab library, I had found the book *The Invertebrates: Protozoa through Ctenophora* by Libby Hyman. She was a renowned Smithsonian biologist who wrote this fabulous collection of books on marine invertebrates. One of them was on ctenophores and there it was -- a description of sessile ctenophores except that all the ones she described were tiny. Here we had this monster. Anyway, we collected several and sent it to a world expert in Japan. Sure enough, he said it was a new species and helped us name it *Lyrocteis flavopallidus*.

PETER: And it has not been found in great numbers since. It's still rare.

PAUL: We collected several.

GORDON: Yes. We were always curious about how they got to our study areas because we had never seen one on the bottom and we had spent a lot of hours looking carefully at the benthic habitat. The first one we saw was on a steel pole that we had put in the ground at about 90 feet for marking something else. We never saw them until then. We assumed that it had moved along the bottom and just crept up the pole so that it was on a high point where it could extend its tentacles to feed in the water column without competition from other filter and suspension

feeders. Unfortunately, when you preserve them they turn into a ball of mush so it's not exciting at all. The pictures are more exciting.

PAUL: It took several tries to preserve this ctenophore. We relaxed it in magnesium chloride, which took a long time, and then we very slowly added formalin to the solution because we found out with the first ones that if we added formalin too fast, the ctenophore "shatters". We harden it with formalin and then infused it with a special wax around it to keep the ball of mush from breaking up. The type specimen is just this ball of wax. If somebody wants to do additional anatomical studies on it, they will have to cut up the wax and get the fine structure.

So we basically collected hard on the population in the diving depth. However, a couple years ago when we went back with the ROV, we found that there are a fair number of them.

PETER: Deeper?

PAUL: Yes, just below where we collected them in the first years. And they show up in journal literature in different places.

GORDON: I would be surprised if it was a rare species.

PAUL: But that was fun because it was totally new.

Another challenge that we faced. In the first year, we determined that the next year we would need a third person on the team so we had a tender and some diving help. Because in the first year, I had seen bacterial issues that excited me, I really wanted to get a bacteriologist to help me with the bacteriology. So I went to a grad

student at UW who was doing bacteria studies and was familiar enough with scuba diving to be a tender. He agreed and we went through getting him all lined up to come to the Ice the second year. But he flunked his physical at the last minute in the summer because he had what they thought might be an ulcer. Those doctors were really careful. I doubt that he had an ulcer or whatever it was, but my opinion was outweighed by actual MDs, so he couldn't go.

Then at the very last minute, we got another student (Charles “Chuck” Galt) at UW. He was very methodical, he worked slowly, and he turned out to be good at any task assigned to him. You gave him a job and he'd do it. I had Rick, the bacteriologist (with the ulcer!) train Chuck how to do the basics of bacteriological tests and analyses. Chuck helped us with the dives as a tender and also participated in some dives. He was very good at making agar gels. The agar is placed in a Petri dish and the agar has different nutrients mixed in it. You smear the test material on the agar and almost overnight, in normal situations, you get a little stain of bacteria. In two or three days, you get beautiful colors in the smears. The bacteriologists can usually define the species based on the nutrients in the agar and the source of whatever was used to make the smear. At least, that's how they did it in those days. We had all these different types of nutrients so we could look at the different species. Chuck put plates of stained agar in the coldest refrigerator that we had in the BioLab. It was plus 1 (~34^{o}F) rather than minus 2 (~28^{o}F) in the natural marine environment. The bacteria cultures should have grown fast because they're warmer than

ambient, but nothing happened.

Just nothing happened for several weeks! We were looking at them regularly at first, but because nothing was happening, we forgot about them. When we wrapping up to go home, I went to the fridge to clean it up and throw the agar plates away. To my surprise, they had all been growing over the month and a half that I hadn't looked at them. They had the streaks of various bacteria -- just everything was perfect! The anomaly was that the growth should have happened in four days, max, but it took nearly three months.

This set me off on a long period of frustrating work trying to get bacteriology done. We (my later grad students and I) continued to look into the bacteriological issues in this cold water environment and we got part way there in the '80s before my program got cut off. I still regret it because bacteria drive the benthic systems and the Antarctic benthic environment seems to be a very different place from most of those studied in temperate/tropical areas. It would be really good to have had that done well and learned more about the role and dynamics of bacteria in the McMurdo marine system.

Bacteriological studies are hard to do well *in situ* in the Antarctic because you have to go deep where it is too cold to stay long enough to complete the work. Plus the bacteria growth dynamics are too slow. In the '80s, Judi Hanson and I were trying to do these *in situ* studies. We were lying there with syringes and other equipment. We were just freezing because we had to remain motionless so we did not stir stuff up inside the chambers. It worked but they were so slow she did

not believe it and we continued on it the second of a three year grant and finally she was convinced that the slow growth was real. It didn't work but she took a whole year to convince herself that Antarctic bacteria grow that slowly. And they did. And just as we had the third year to collect the definitive data, I was cut out of the Antarctic program for reasons that are still not clear to me, a personal vendetta I believe. The program had become such a logistical nightmare that the only thing I really regret was being robbed of the opportunity to publish those data.

PETER: Did you see dead Weddell seals on the bottom?

GORDON: Yes.

PAUL: In Shackleton's expedition, the crew was stranded at Cape Evans because their ship was forced out to sea with a lot of supplies that they could not unload in time. The shore-bound crew had to lay in a lot of seal meat and blubber. We knew that much just from reading about the various expeditions and the hardships that they endured as well as how they provisioned themselves to survive. When we made our first dive at Cape Evans in 1967, there was a lot of the historical debris on the bottom – cans, metal, whiskey bottles and other bottles, etc. What really stood out were big white blobs all over the place; there were probably 20 or 30 anyway.

We didn't know what they were. I finally went in and picked some of them apart to discover that they were dead seals. The white filamentous stuff was bacteria. At first I thought they were "Shackleton's" seals preserved by the bacteria or at least from that era. Actually the dead seals may have been something killed to feed dog teams

maintained by both the New Zealand and American bases. But in any case they certainly were taking years to decompose; much longer than anyplace else I had ever heard of.

In general what happens with the bacteria decomposing a large object is that aerobic bacteria, often *Beggiatoa*, forms a layer on top which uses oxygen. This outer layer protects a layer of anaerobic bacteria underneath that are killed by oxygen and they are sulfide-producing bacteria. When some animal, like a starfish or sea urchin that normally eats bacteria walks onto that seal and begins to eat the white outer layer of aerobic bacteria, the sulfur underneath is released and it can kill them. So you have this “time bomb” of a slowly-decomposing seal that's protected by aerobic bacteria on the top and the deadly anaerobic ones below.

Eventually John Oliver and I did a bunch of experiments. We got dead seals from several sources including other researchers who were doing physiological experiments and from the Kiwis who fed seal meat to their dogs. We sank these dead seals in different places around our study area. Not much happened. They got covered with white bacteria. Over the several years that I was able to find and re-assess them, they didn't change much. Much later John Oliver reported seeing them in more advanced decomposition, but surely we are looking at several years, perhaps over a decade, for a dead seal to decompose from bacterial action.

GORDON: This was remarkably slower than the same process in the Arctic where large fish carcasses are devoured by

amphipods almost before they hit the bottom. I never saw bacterial mats like we did in the Antarctic.

PETER: The sea stars knew they were unsavory.

PAUL: We could see where the urchins tried to get into the mass of the bacteria, but we could also see that there were urchin tests around. The urchins get in slowly, they rear back and use the tips of their spines to break up the bacteria mat a little bit, and then they move in and eat it. So we'd see a little ring of urchins trying to do that. Then there's a ring of dead sea urchin tests which were the ones that the sulphur gas killed.

PETER: What depth?

PAUL: 140 feet.

GORDON: I've got pictures of one seal that we found at about 70 feet at Hut Point. It was obviously a fresh carcass, likely one that died in the course of the physiological experiments being done by another group or possibly one that was mortally wounded but escaped from the Kiwis who fed the meat to their dogs.

The amphipods got into the carcass and the decomposition of these fresh carcasses was an interesting contrast to the bacterial degradation process that Paul is describing. The differences are likely a little dependent on serendipity; that is who gets there first and establishes dominance if you will. Once the amphipods got there, they clean the carcass right out.

PAUL: In a few days.

GORDON: Yes. So we hypothesized that if the

amphipods don't find and start to scavenge the carcass quickly, maybe the bacteria have a chance to establish the aerobic layer of bacteria over the carcass and prevent further rapid decomposition.

PAUL: That's why we did this work at New Harbor, where we knew that the amphipods that seemed constrained to gravel and spicule habitats were less likely to consume the seal before the bacterial communities could be established.

GORDON: As we are getting to the wrap-up point here, we might provide some perspectives on this 2-year program and how it influenced our futures. For me, there was a real long-term benefit of this program working in a remote, polar marine habitat. It was the first time ever working in polar waters, despite Peter's observation that Paul and I were diving in British Columbia and Washington waters where it is obviously cold (for a southern Californian!). When I left graduate school and got a real job, I started working in the Arctic marine environment a lot. I did a lot of diving at Prudhoe Bay in the Arctic Ocean. The Antarctic experience made me a lot more capable of handling the planning and logistics or a remote diving program. Based on the McMurdo experience, I was able to do many of the same kind of things in the Arctic. At the same time, I realized immediately on the first dive that the Arctic habitat is very different from the Antarctic. The Arctic, at least in the western Beaufort Sea, is a shallow water, muddy environment where the broken sea ice has a lot more effect on the bottom with gouging, scraping and generally impacting the bottom. Physical factors are much more important in the structure of the benthic

community at Prudhoe Bay than they are at McMurdo (though some of this is likely due to the much shallower depths at Prudhoe Bay.). We would see anchor ice sometimes but not very much. The lack of physical stability in the Arctic community creates a flat, muddy plain with some polychaete worms, clams, tube dwelling amphipods and other crustaceans, and not much else. It was one of the most boring shallow water marine benthic communities in the world (in my opinion).

Still, the background of the Antarctic benthic community work helped me a lot to look at the Arctic communities and begin to ask the right questions to learn how it might be impacted by the various projects that were planned. That ability to ask questions about what I was seeing was helped immeasurably by working with Paul at McMurdo and trying to emulate his approach to asking, “Why is that happening and what are the ramifications of it to the rest of the community?” Diving in the Arctic was similar to what we were doing in the Antarctic, just shallower. Logistically, I knew what to do and what kind of equipment was needed.

PAUL: I want to elaborate on a couple of other discoveries or confirmations from work we did in the 1960s. The anchor ice dynamics that Gordon described earlier was described in the anchor ice paper that we wrote. We described how rocks, animals, and other things were lifted up and frozen into the bottom of the sea ice cover. It turned out to be a fairly important paper. People didn't realize that John Pearse had written an earlier letter to the editor of Scientific America about the anchor ice phenomenon. He nailed it because he also had seen

it. But it was one paragraph. I didn't know about John's letter until after we came home and started writing our paper on the anchor ice.

The anchor ice paper describes something that had bedeviled the geologists and glaciologists because they often saw benthic organisms in the ice and did not understand how they got there.

Others had observed these fragile sponges, clams, bryozoans, and all sorts of benthic creatures sitting on top of the ice and not broken. What we saw was how these things are just lifted up. In the scientific, expedition and "popular" literature which went back to Frank Debenham, who was on Scott's expedition and to another fellow named Charles Swithinbank, there is discussion about the presence of these critters but they just said it was the glacier moving across a benthic habitat and just slowly sort of grinding it up to the surface of the sea ice. But the benthic critters, many of which were far to delicate to "ground up" or "pushed along", weren't ground up so it was a problem – the observations did not support the explanation.

When our paper came out, I got a letter from Swithinbank saying, "Finally, this makes sense". That was very satisfying. We made the observations, described the mechanism and resolved a decades-old dilemma - we really did something for Antarctic science!

Another thing that oceanographers know about is the loss of the salt out of sea ice. The sea ice forms by freezing the upper layer of the marine water and, in doing so, some of the salt is retained in the ice; it's salty. For various physical reasons, the salt accumulates in

pockets and it melts it way down. As it does so, it gets more and more salty. This eroding brine melts its way through the bottom of the sea ice. It's really cold brine, because it's been up where the air temperature is really cold and much colder than the seawater.

That cold brine flows down and, when you are underwater, you can see the brine coming down because it is so much denser (i.e., saltier) than the seawater. It immediately freezes the seawater around the flow and makes these wonderful stalactites which we photograph so often.

The stalactites will sometimes hit the bottom and the brine goes along the bottom making an “ice crystal tunnel” that encases the brine. Eventually the brine reaches both temperature and salinity equilibrium with the surrounding seawater and the stalactite disappears. We published a paper on that around 1971.

And it's sort of interesting because the British have publicized it, showing a time lapse video which is a big deal in the media now. And we were all over that.

GORDON: If we had a video cam are in 1968, we would have had a lot of great footage of these stalactites growing. I actually saw what Paul described where the brine broke through and I just watched a stalactite form for about ten minutes. That brine is probably -10 to 15^{o}F, maybe colder.

PAUL: We were decompressing so we had time to waste under the ice. So we watched that a lot.

PETER: That's where image technology held you back,

because with film, you were very constrained

GORDON: A lot of the stuff that Paul did with community dynamics, et cetera, based on manual analysis of one black and white photograph after another, would be done a lot more quickly now.

PAUL: And an ROV would also have made the original collection of images a lot more efficient and effective.

GORDON: Yeah. But had to get started somewhere.

PAUL: Can you think of anything else we should talk about? I think we've basically tried here to cover the 1960s. We had some jumps into the 1970s. Much of the more recent stuff is published so I'm not sure it's history. At the very least I want to acknowledge the great leadership and wisdom and integrity of George Llano and John Twiss.

GORDON: My last comment is that, of all the places I've been diving in the world, this has got to be the most incredible. The only drawback was the cold water. But I'd do it again even with that cold. That is, I would if I could!

PAUL: I'd do it in a flash if I could also.